

# VERSION 5

## DEPARTMENT OF THE NAVY (DON) 21.2 Small Business Innovation Research (SBIR) Proposal Submission Instructions

### IMPORTANT

- The following instructions apply to SBIR topics only:
  - N212-101 through N212-139
- The information provided in the DON Proposal Submission Instruction document takes precedence over the DoD Instructions posted for this Broad Agency Announcement (BAA).
- DON Phase I Technical Volume (Volume 2) page limit is not to exceed 10 pages.
- Proposers that are more than 50% owned by multiple venture capital operating companies (VCOC), hedge funds (HF), private equity firms (PEF) or any combination of these are eligible to submit proposals in response to DON topics advertised in this BAA. Information on Majority Ownership in Part and certification requirements at time of submission for these proposers are detailed in the section titled **ADDITIONAL NOTES**.
- A Phase I Technical Volume (Volume 2) proposal template, specific to DON topics, is available at [https://www.navysbir.com/links\\_forms.htm](https://www.navysbir.com/links_forms.htm); use this template to meet Volume 2 requirements.
- The DON provides notice that Basic Ordering Agreements (BOAs) may be used for Phase I awards, and BOAs or Other Transaction Agreements (OTAs) may be used for Phase II awards.
- The Supporting Documents Volume (Volume 5) is available for the SBIR 21.2 BAA cycle. The Supporting Documents Volume is provided for small businesses to submit additional documentation to support the Technical Volume (Volume 2) and the Cost Volume (Volume 3). Volume 5 is available for use when submitting Phase I and Phase II proposals. DON will not be using any of the information in Volume 5 during the evaluation.

### INTRODUCTION

The Director of the DON SBIR/STTR Programs is Mr. Robert Smith. For questions regarding this BAA, use the information in Table 1 to determine who to contact for what types of questions.

**TABLE 1: POINTS OF CONTACT FOR QUESTIONS REGARDING THIS BAA**

Type of Question	When	Contact Information
Program and administrative	Always	Program Managers list in Table 2 (below)
Topic-specific technical questions	BAA Pre-release	Technical Point of Contact (TPOC) listed in each topic. Refer to section 4.13 of the DoD BAA for details.
	BAA Open	DoD SBIR/STTR Topic Q&A platform ( <a href="https://www.dodsbirsttr.mil/submissions">https://www.dodsbirsttr.mil/submissions</a> ) Refer to section 4.13 of the DoD BAA for details.

## VERSION 5

Electronic submission to the DoD SBIR/STTR Innovation Portal (DSIP)	Always	DoD Help Desk via email at <a href="mailto:dodsbirsupport@reisystems.com">dodsbirsupport@reisystems.com</a>
Navy-specific BAA instructions and forms	Always	Navy-sbir-sttr.fct@navy.mil

**TABLE 2: DON SYSTEMS COMMAND (SYSCOM) SBIR PROGRAM MANAGERS**

<u>Topic Numbers</u>	<u>Point of Contact</u>	<u>SYSCOM</u>	<u>Email</u>
N212-101 to N212-102	Mr. Jeffrey Kent	Marine Corps Systems Command (MCSC)	jeffrey.a.kent@usmc.mil
N212-103 to N212-118	Ms. Donna Attick	Naval Air Systems Command (NAVAIR)	navair.sbir@navy.mil
N212-119	Mr. Shadi Azoum	Naval Information Warfare Systems Command (NAVWAR)	shadi.azoum@navy.mil
N212-120 to N212-129	Ms. Lore-Anne Ponirakis	Office of Naval Research (ONR)	loreanne.ponirakis@navy.mil
N212-130 to N212-139	Mr. Michael Pyryt	Strategic Systems Programs (SSP)	michael.pyryt@ssp.navy.mil

The DON SBIR/STTR Programs are mission-oriented programs that integrate the needs and requirements of the DON's Fleet through research and development (R&D) topics that have dual-use potential, but primarily address the needs of the DON. More information on the programs can be found on the DON SBIR/STTR website at [www.navysbir.com](http://www.navysbir.com). Additional information pertaining to the DON's mission can be obtained from the DON website at [www.navy.mil](http://www.navy.mil).

### PHASE I GUIDELINES

Follow the instructions in the DoD SBIR/STTR Program BAA on the DoD SBIR/STTR Innovation Portal (DSIP), <https://www.dodsbirsttr.mil/submissions>, for requirements and proposal submission guidelines. Please keep in mind that Phase I must address the feasibility of a solution to the topic. It is highly recommended that proposers use the Phase I proposal template, specific to DON topics, at [https://navysbir.com/links\\_forms.htm](https://navysbir.com/links_forms.htm) to meet Phase I Technical Volume (Volume 2) requirements. Inclusion of cost estimates for travel to the sponsoring SYSCOM's facility for one day of meetings is recommended for all proposals.

Proposers are required to submit proposals via DSIP; proposals submitted by any other means will be disregarded. Proposers submitting through this site for the first time will be asked to register. It is recommended that firms register as soon as possible upon identification of a proposal opportunity to avoid delays in the proposal submission process. Proposals that are not successfully certified in DSIP prior to BAA Close will NOT be considered submitted. Please refer to section 5.1 of the DoD SBIR/STTR Program BAA for further information.

# VERSION 5

## PHASE I PROPOSAL SUBMISSION REQUIREMENTS

The following MUST BE MET or the proposal will be deemed noncompliant and shall be REJECTED.

- **Proposal Cover Sheet (Volume 1).** As specified in DoD SBIR/STTR Program BAA section 5.4(a).
- **Technical Proposal (Volume 2).** Technical Proposal (Volume 2) must meet the following requirements:
  - Content is responsive to evaluation criteria as specified in DoD SBIR/STTR Program BAA section 6.0
  - Not to exceed **10** pages, regardless of page content
  - Single column format, single-spaced typed lines
  - Standard 8 ½” x 11” paper
  - Page margins one-inch on all sides. A header and footer may be included in the one-inch margin.
  - No font size smaller than 10-point\*
  - Include, within the **10-page limit of Volume 2**, an Option that furthers the effort in preparation for Phase II and will bridge the funding gap between the end of Phase I and the start of Phase II. Tasks for both the Phase I Base and the Phase I Option must be clearly identified. Phase I Options are exercised upon selection for Phase II.

\*For headers, footers, and imbedded tables, figures, images, or graphics that include text, a font size smaller than 10-point is allowable; however, proposers are cautioned that if the text is too small to be legible it will not be evaluated.

Volume 2 is the technical proposal. Additional documents may be submitted to support Volume 2 in accordance with the instructions for Supporting Documents Volume (Volume 5) as detailed below.

### **Disclosure of Information (DFARS 252.204-7000)**

In order to eliminate the requirements for prior approval of public disclosure of information (in accordance with DFARS 252.204-7000) under this or any subsequent award, the proposer shall identify and describe all fundamental research to be performed under its proposal, including subcontracted work, with sufficient specificity to demonstrate that the work qualifies as fundamental research. Fundamental research means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons. Simply identifying fundamental research in the proposal does NOT constitute acceptance of the exclusion. All exclusions will be reviewed and noted in the award. NOTE: Fundamental research included in the technical proposal that the proposer is requesting be eliminated from the requirements for prior approval of public disclosure of information, must be uploaded in a separate document (under “Other”) in the Supporting Documents Volume (Volume 5).

- **Cost Volume (Volume 3).** The Phase I Base amount must not exceed \$140,000 and the Phase I Option amount must not exceed \$100,000. Costs for the Base and Option must be separated and clearly identified on the Proposal Cover Sheet (Volume 1) and in Volume 3.

## VERSION 5

- **Period of Performance.** The Phase I Base Period of Performance must be exactly six (6) months and the Phase I Option Period of Performance must be exactly six (6) months.
- **Company Commercialization Report (Volume 4).** DoD requires Volume 4 for submission to the 21.2 Phase I BAA. Please refer to instructions provided in section 5.4.e of the DoD SBIR/STTR Program BAA.
- **Supporting Documents (Volume 5).** Volume 5 is available for use when submitting Phase I and Phase II proposals.

The DoD must comply with Section 889(a)(1)(B) of the FY2019 National Defense Authorization Act (NDAA) and is working to reduce or eliminate contracts, or extending or renewing a contract with an entity that uses any equipment, system, or service that uses covered telecommunications equipment or services as a substantial or essential component of any system, or as critical technology as part of any system. **As such, all proposals must include as a part of their submission a written certification in response to the NDAA clauses (Federal Acquisition Regulation clauses 52.204-24, 52-204-25 and 52-204-26).** The written certification can be found in Attachment 1 of the DoD SBIR/STTR Program BAA. This certification must be signed by the authorized company representative and is to be uploaded as a separate PDF file in Volume 5. Failure to submit the required certification as a part of the proposal submission process will be cause for rejection of the proposal submission without evaluation. Please refer to instructions provided in section 5.4.g of the DoD SBIR/STTR Program BAA.

In accordance with DFARS provision 252.209-7002, a proposer is required to disclose any interest a foreign government has in the proposer when that interest constitutes control by foreign government. Proposers must review the Foreign Ownership or Control Disclosure information to determine applicability. If applicable, an authorized firm representative must complete the Disclosure of Offeror's Ownership or Control by a Foreign Government (found in Attachment 2 of the DoD SBIR/STTR Program BAA) and upload as a separate PDF file in Volume 5. Please refer to instructions provided in section 5.4.h of the DoD SBIR/STTR Program BAA.

Volume 5 is available for small businesses to submit additional documentation to support the Technical Proposal (Volume 2) and the Cost Volume (Volume 3). A template is available on [https://navysbir.com/links\\_forms.htm](https://navysbir.com/links_forms.htm). DON will not be using any of the information in Volume 5 during the evaluation.

- Additional Cost Information
- SBIR/STTR Funding Agreement Certification
- Data Rights
- Allocation of Rights between Prime and Subcontractor
- Disclosure of Information (DFARS 252.204-7000)
- Prior, Current, or Pending Support of Similar Proposals or Awards
- Foreign Citizens
- Majority-Owned VCOC, HF, and PEF Certification, if applicable

NOTE: The inclusion of documents or information other than that listed above (e.g., resumes, test data, technical reports, publications) may result in the proposal being deemed “Non-compliant” and REJECTED.

A font size smaller than 10-point is allowable for documents in Volume 5; however, proposers are cautioned that the text may be unreadable.

## VERSION 5

- **Fraud, Waste and Abuse Training Certification (Volume 6).** DoD requires Volume 6 for submission to the 21.2 Phase I BAA. Please refer to instructions provided in section 5.4.i of the DoD SBIR/STTR Program BAA.

### DON SBIR PHASE I PROPOSAL SUBMISSION CHECKLIST

- **Subcontractor, Material, and Travel Cost Detail.** In the Cost Volume (Volume 3), proposers must provide sufficient detail for subcontractor, material, and travel costs. Subcontractor costs must be detailed to the same level as the prime contractor. Material costs must include a listing of items and cost per item. Travel costs must include the purpose of the trip, number of trips, location, length of trip, and number of personnel. The “Additional Cost Information” of Volume 5 may be used if additional space is needed to detail these costs. When a proposal is selected for award, be prepared to submit further documentation to the SYSCOM Contracting Officer to substantiate costs (e.g., an explanation of cost estimates for equipment, materials, and consultants or subcontractors).
- **Performance Benchmarks.** Proposers must meet the two benchmark requirements for progress toward Commercialization as determined by the Small Business Administration (SBA) on June 1 each year. Please note that the DON applies performance benchmarks at time of proposal submission, not at time of contract award.
- **Discretionary Technical and Business Assistance (TAB A).** If TAB A is proposed, the information required to support TAB A (as specified in the TAB A section below) must be included in Volume 5 as “Additional Cost Information”. Failure to include the required information in Volume 5 will result in the denial of TAB A. The total value of TAB A must not exceed \$6,500 in Phase I.

### DISCRETIONARY TECHNICAL AND BUSINESS ASSISTANCE (TAB A)

The SBIR and STTR Policy Directive section 9(b) allows the DON to provide TAB A (formerly referred to as DTA) to its awardees. The purpose of TAB A is to assist awardees in making better technical decisions on SBIR/STTR projects; solving technical problems that arise during SBIR/STTR projects; minimizing technical risks associated with SBIR/STTR projects; and commercializing the SBIR/STTR product or process, including intellectual property protections. Firms may request, in their Phase I Cost Volume (Volume 3) and Phase II Cost Volume, to contract these services themselves through one or more TAB A providers in an amount not to exceed the values specified below. The Phase I TAB A amount is up to \$6,500 and is in addition to the award amount. The Phase II TAB A amount is up to \$25,000 per award. The TAB A amount, of up to \$25,000, is to be included as part of the award amount and is limited by the established award values for Phase II by the SYSCOM (i.e. within the \$1,700,000 or lower limit specified by the SYSCOM). As with Phase I, the amount proposed for TAB A cannot include any profit/fee application by the SBIR/STTR awardee and must be inclusive of all applicable indirect costs. A Phase II project may receive up to an additional \$25,000 for TAB A as part of one additional (sequential) Phase II award under the project for a total TAB A award of up to \$50,000 per project. A TAB A Report, detailing the results and benefits of the service received, will be required annually by October 30.

Approval of direct funding for TAB A will be evaluated by the DON SBIR/STTR Program Office. If the TAB A request does not include the following items the TAB A request will be denied.

- TAB A provider(s) (firm name)
- TAB A provider(s) point of contact, email address, and phone number
- An explanation of why the TAB A provider(s) is uniquely qualified to provide the service
- Tasks the TAB A provider(s) will perform

## VERSION 5

- Total TABA provider(s) cost, number of hours, and labor rates (average/blended rate is acceptable)

TABA must NOT:

- Be subject to any profit or fee by the SBIR applicant
- Propose a TABA provider that is the SBIR applicant
- Propose a TABA provider that is an affiliate of the SBIR applicant
- Propose a TABA provider that is an investor of the SBIR applicant
- Propose a TABA provider that is a subcontractor or consultant of the requesting firm otherwise required as part of the paid portion of the research effort (e.g., research partner, consultant, tester, or administrative service provider)

TABA requests must be included as follows:

- Phase I:
  - Online DoD Cost Volume (Volume 3) – the value of the TABA request.
  - Supporting Documents Volume (Volume 5) – a detailed request for TABA (as specified above) specifically identified as “Discretionary Technical and Business Assistance”.
- Phase II:
  - DON Phase II Cost Volume (provided by the DON SYSCOM) - the value of the TABA request.
  - Volume 5 – a detailed request for TABA (as specified above) specifically identified as “Discretionary Technical and Business Assistance”.

Proposed values for TABA must NOT exceed:

- Phase I: A total of \$6,500
- Phase II: A total of \$25,000 per award, not to exceed \$50,000 per Phase II project

If a proposer requests and is awarded TABA in a Phase II contract, the proposer will be eliminated from participating in the DON SBIR/STTR Transition Program (STP), the DON Forum for SBIR/STTR Transition (FST), and any other assistance the DON provides directly to awardees.

All Phase II awardees not receiving funds for TABA in their awards must attend a one-day DON STP meeting during the first or second year of the Phase II contract. This meeting is typically held in the spring/summer in the Washington, D.C. area. STP information can be obtained at: <https://navystp.com>. Phase II awardees will be contacted separately regarding this program. It is recommended that Phase II cost estimates include travel to Washington, D.C. for this event.

### EVALUATION AND SELECTION

The DON will evaluate and select Phase I and Phase II proposals using the evaluation criteria in Sections 6.0 and 7.0 of the DoD SBIR/STTR Program BAA respectively, with technical merit being most important, followed by qualifications of key personnel and commercialization potential of equal importance. Due to limited funding, the DON reserves the right to limit the number of awards under any topic.

Approximately one week after the Phase I BAA closing, e-mail notifications that proposals have been received and processed for evaluation will be sent. Consequently, the e-mail address on the proposal Cover Sheet must be correct.

Requests for a debrief must be made within 15 calendar days of select/non-select notification via email as specified in the select/non-select notification. Please note debriefs are typically provided in writing via email to the Corporate Official identified in the firm proposal within 60 days of receipt of the request. Requests for oral debriefs may not be accommodated. If contact information for the Corporate Official has



## VERSION 5

changed since proposal submission, a notice of the change on company letterhead signed by the Corporate Official must accompany the debrief request.

Protests of Phase I and II selections and awards must be directed to the cognizant Contracting Officer for the DON Topic Number, or filed with the Government Accountability Office (GAO). Contact information for Contracting Officers may be obtained from the DON SYSCOM Program Managers listed in Table 2. If the protest is to be filed with the GAO, please refer to instructions provided in section 4.11 of the DoD SBIR/STTR Program BAA.

Protests to this BAA and proposal submission must be directed to the DoD SBIR/STTR Program BAA Contracting Officer, or filed with the GAO. Contact information for the DoD SBIR/STTR Program BAA Contracting Officer can be found in section 4.11 of the DoD SBIR/STTR Program BAA.

### CONTRACT DELIVERABLES

Contract deliverables for Phase I are typically a kick-off brief, progress reports, and a final report. Required contract deliverables must be uploaded to <https://www.navysbirprogram.com/navydeliverables/>.

### AWARD AND FUNDING LIMITATIONS

Awards. The DON typically awards a Firm Fixed Price (FFP) contract or a small purchase agreement for Phase I. In addition to the negotiated contract award types listed in Section 4.12.b of the DoD SBIR/STTR Program BAA, for Phase II awards the DON may (under appropriate circumstances) propose the use of an Other Transaction Agreement (OTA) as specified in 10 U.S.C. 2371/10 U.S.C. 2371b and related implementing policies and regulations. The DON may choose to use a Basic Ordering Agreement (BOA) for Phase I and Phase II awards.

Funding Limitations. In accordance with the SBIR and STTR Policy Directive section 4(b)(5), there is a limit of one sequential Phase II award per firm per topic. Additionally, to adjust for inflation DON has raised Phase I and Phase II award amounts. The maximum Phase I proposal/award amount including all options (less TABA) is \$240,000. The Phase I Base amount must not exceed \$140,000 and the Phase I Option amount must not exceed \$100,000. The maximum Phase II proposal/award amount including all options (including TABA) is \$1,700,000 (unless non-SBIR/STTR funding is being added). Individual SYSCOMs may award amounts, including Base and all Options, of less than \$1,700,000 based on available funding. The structure of the Phase II proposal/award, including maximum amounts as well as breakdown between Base and Option amounts will be provided to all Phase I awardees either in their Phase I award or a minimum of 30 days prior to the due date for submission of their Initial Phase II proposal.

### PAYMENTS

The DON makes three payments from the start of the Phase I Base period, and from the start of the Phase I Option period, if exercised. Payment amounts represent a set percentage of the Base or Option value as follows:

Days From Start of Base Award or Option	Payment Amount
15 Days	50% of Total Base or Option
90 Days	35% of Total Base or Option
180 Days	15% of Total Base or Option

### TRANSFER BETWEEN SBIR AND STTR PROGRAMS

Section 4(b)(1)(i) of the SBIR and STTR Policy Directive provides that, at the agency's discretion, projects awarded a Phase I under a BAA for SBIR may transition in Phase II to STTR and vice versa. Please refer to instructions provided in section 7.2 of the DoD SBIR/STTR Program BAA.

# VERSION 5

## ADDITIONAL NOTES

Majority Ownership in Part. Proposers which are more than 50% owned by multiple venture capital operating companies (VCOC), hedge funds (HF), private equity firms (PEF), or any combination of these as set forth in 13 C.F.R. § 121.702, are eligible to submit proposals in response to DON topics advertised within this BAA.

For proposers that are a member of this ownership class the following must be satisfied for proposals to be accepted and evaluated:

- a. Prior to submitting a proposal concerns must register with the SBA Company Registry Database.
- b. The proposer within its submission must submit the Majority-Owned VCOC, HF, and PEF Certification. A copy of the SBIR VC Certification can be found on [https://navysbir.com/links\\_forms.htm](https://navysbir.com/links_forms.htm). Include the SBIR VC Certification in the Supporting Documents Volume (Volume 5).
- c. Should a proposer become a member of this ownership class after submitting its application and prior to any receipt of a funding agreement, the proposer must immediately notify the Contracting Officer, register in the appropriate SBA database, and submit the required certification which can be found on [https://navysbir.com/links\\_forms.htm](https://navysbir.com/links_forms.htm).

System for Award Management (SAM). It is strongly encouraged that proposers register in SAM, <https://beta.sam.gov>, by the Close date of this BAA, or verify their registrations are still active and will not expire within 60 days of BAA Close. Additionally, proposers should confirm that they are registered to receive contracts (not just grants) and the address in SAM matches the address on the proposal.

Human Subjects, Animal Testing, and Recombinant DNA. Due to the short timeframe associated with Phase I of the SBIR/STTR process, the DON does not recommend the submission of Phase I proposals that require the use of Human Subjects, Animal Testing, or Recombinant DNA. For example, the ability to obtain Institutional Review Board (IRB) approval for proposals that involve human subjects can take 6-12 months, and that lengthy process can be at odds with the Phase I goal for time-to-award. Before the DON makes any award that involves an IRB or similar approval requirement, the proposer must demonstrate compliance with relevant regulatory approval requirements that pertain to proposals involving human, animal, or recombinant DNA protocols. It will not impact the DON's evaluation, but requiring IRB approval may delay the start time of the Phase I award and if approvals are not obtained within two months of notification of selection, the decision to award may be terminated. If the use of human, animal, and recombinant DNA is included under a Phase I or Phase II proposal, please carefully review the requirements at: <http://www.onr.navy.mil/About-ONR/compliance-protections/Research-Protections/Human-Subject-Research.aspx>. This webpage provides guidance and lists approvals that may be required before contract/work can begin.

Government Furnished Equipment (GFE). Due to the typical lengthy time for approval to obtain GFE, it is recommended that GFE is not proposed as part of the Phase I proposal. If GFE is proposed and it is determined during the proposal evaluation process to be unavailable, proposed GFE may be considered a weakness in the proposal.

International Traffic in Arms Regulation (ITAR). For topics indicating ITAR restrictions or the potential for classified work, limitations are generally placed on disclosure of information involving topics of a classified nature or those involving export control restrictions, which may curtail or preclude the involvement of universities and certain non-profit institutions beyond the basic research level. Small businesses must structure their proposals to clearly identify the work that will be performed that is of a basic research nature and how it can be segregated from work that falls under the classification and export



## VERSION 5

control restrictions. As a result, information must also be provided on how efforts can be performed in later phases if the university/research institution is the source of critical knowledge, effort, or infrastructure (facilities and equipment).

Support Contract Personnel for Administrative Functions. Proposers are advised that support contract personnel will be used to carry out administrative functions and may have access to proposals, contract award documents, contract deliverables, and reports. All support contract personnel are bound by appropriate non-disclosure agreements.

### PHASE II GUIDELINES

All Phase I awardees can submit an **Initial** Phase II proposal for evaluation and selection. The Phase I Final Report, Initial Phase II Proposal, and Transition Outbrief (as applicable) will be used to evaluate the proposer's potential to progress to a workable prototype in Phase II and transition technology to Phase III. Details on the due date, content, and submission requirements of the Initial Phase II Proposal will be provided by the awarding SYSCOM either in the Phase I contract or by subsequent notification.

**NOTE: All SBIR/STTR Phase II awards made on topics from solicitations prior to FY13 will be conducted in accordance with the procedures specified in those solicitations (for all DON topics, this means by invitation only).**

The DON typically awards a Cost Plus Fixed Fee contract for Phase II; but, may consider other types of agreement vehicles. Phase II awards can be structured in a way that allows for increased funding levels based on the project's transition potential. To accelerate the transition of SBIR/STTR-funded technologies to Phase III, especially those that lead to Programs of Record and fielded systems, the Commercialization Readiness Program was authorized and created as part of section 5122 of the National Defense Authorization Act of Fiscal Year 2012. The statute set-aside is 1% of the available SBIR/STTR funding to be used for administrative support to accelerate transition of SBIR/STTR-developed technologies and provide non-financial resources for the firms (e.g., the DON STP).

### PHASE III GUIDELINES

A Phase III SBIR/STTR award is any work that derives from, extends, or completes effort(s) performed under prior SBIR/STTR funding agreements, but is funded by sources other than the SBIR/STTR programs. This covers any contract, grant, or agreement issued as a follow-on Phase III award or any contract, grant, or agreement award issued as a result of a competitive process where the awardee was an SBIR/STTR firm that developed the technology as a result of a Phase I or Phase II award. The DON will give Phase III status to any award that falls within the above-mentioned description, which includes assigning SBIR/STTR Data Rights to any noncommercial technical data and/or noncommercial computer software delivered in Phase III that was developed under SBIR/STTR Phase I/II effort(s). Government prime contractors and/or their subcontractors must follow the same guidelines as above and ensure that companies operating on behalf of the DON protect the rights of the SBIR/STTR firm.

# VERSION 5

## NAVY 21.2 SBIR PHASE I TOPIC INDEX

N212-101	Broadband Counter-Electronics Weapon (BCEW) for Long-Range Non-Lethal Vehicle/Vessel Stopping Capabilities
N212-102	Portable Hydroelectric Generators
N212-103	Multispectral Target and Scene Projector
N212-104	Multimode-Coupled High-Frequency Photoreceiver
N212-105	Zero Foreign Object Damage (FOD): Inlet Debris Monitoring System (IDMS)
N212-106	Fast Low Loss Uninterrupted Optical Switch
N212-107	Novel Feedstock Production System for Metallic Additive Manufactured Structural Parts and Repairs
N212-108	Low-Inclusion Content for High-Grade Steel Material Used in Gear-and-Bearing Components
N212-109	Naval Aircrew Life Preserver Unit Automatic Inflation Device
N212-110	Machine Learning, Tactical Cross-Domain Solution, Cryptography Module
N212-111	Technology for Transmitting and Receiving Airborne, High-Speed, Wideband, Covert Communications
N212-112	Extending the Surveillance Horizon for Improved Ship Self-Defense Against Hypersonic Cruise Missiles
N212-113	Modeling of Solid-State Materials Consolidation Repair Process for Static Strength and Fatigue Life Predictions
N212-114	Advanced Low Probability of Intercept/Low Probability of Detection Radar (LPI/LPD) Techniques Using Artificial Intelligence Driven Methods
N212-115	Additive Fiber Reinforced Composite Repair for Aircraft
N212-116	Acoustic Tomography Using Tactical Sensors
N212-117	Infrared (IR) Optical Windows for Hypersonic Aerial Vehicles
N212-118	Integrated Low-Jitter Mode-Locked Source for Optical Signal Processing Applications
N212-119	Mobile User Objective System Dynamic Scanning Improvement

## VERSION 5

N212-120	Development of Non-Toxic but BioFouling Deterrent Marine Coatings
N212-121	Improved Marx Pulse Generator for High Power Microwave (HPM) Systems
N212-122	Characterizing 5G vulnerabilities in an expeditionary environment
N212-123	External Payload Deployment System for Cylindrical UUVs
N212-124	Low-cost Mid-wave Infrared Focal-Plane Arrays through Direct-on-Read Out Integrated Circuit Detector Fabrication
N212-125	Mobile Electrocardiogram Monitor for Bottlenose Dolphins in the Marine Environment
N212-126	GHz Optical Underwater Detection Receiver
N212-127	High-Temperature Fuel Coking Mitigation Frangible Coatings for Fuel Nozzles and Screens
N212-128	Publicly Available Information Analysis Curation Tool
N212-129	Components for a Deep Operating Unmanned Underwater Vehicle
N212-130	Integrated Sensor Technologies for Composites
N212-131	Innovative Manufacturing/Materials for Structural Insulators in Hypersonic Flight Body Thermal Protection Systems
N212-132	Large Footprint Silicon Leadless Chip Carrier (LCC)
N212-133	Microfabricated Noble Gas Vacuum Pump
N212-134	Moderate Spectral Resolution Spectrometer
N212-135	Development of a Widely Applicable Supporting Optical Circuit in Micro Optics
N212-136	Development of Predictive Aero-Optical Models of the Hypersonic Environment
N212-137	High Efficiency, Low Size Weight and Power (SWaP) Solid State Power Amplifiers (SSPAs) for Sensor Applications
N212-138	Advanced Persistent-Surveillance Sky Camera
N212-139	Radiation Hard Mid-Wave Infrared Imagers

# VERSION 5

N212-101 TITLE: Broadband Counter-Electronics Weapon (BCEW) for Long-Range Non-Lethal Vehicle/Vessel Stopping Capabilities

RT&L FOCUS AREA(S): Autonomy;Directed Energy (DE);Microelectronics

TECHNOLOGY AREA(S): Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop a compact/lightweight low-cost broadband/wideband high-power microwave (HPM) source to support intermediate force capabilities, i.e., a long-range vehicle and/or vessel engine stopping system. Provide wideband (100 MHz to 2 GHz) HPM sources with pulse widths of 1 nanosecond (ns) to 200 nanoseconds; pulse repetition frequencies of a few pulses per second to 100 kHz; HPM waveform rise times of 0.25 ns to 100 ns; Electronic Field Strengths of 1kV/meter to 100 kV/meter; polarizations of horizontal or vertical; overall system size and weight of less than 100 lbs threshold (T), 50 lbs objective (O); and a low overall system cost of < \$100K (T); \$50K (O); effective ranges of 100's of meters (T) and a few kilometers (3-5km) (O).

**DESCRIPTION:** This SBIR topic seeks to develop a more compact and lightweight long-range counter-electronic vehicle/vessel stopping system to support long range non-lethal vehicle/vessel stopping missions; and to mitigate codified joint non-lethal weapon capability gaps. There is Service transition interest in both the Maritime (U.S. Navy and U.S. Coast Guard) and Ground (U.S. Army and USMC) domains as each Service currently desires long-range threat vehicle/vessel stopping capabilities with significant reduced overall system size, weight, power consumption, thermal cooling and lower system costs (SWAP/C2). Existing Radio Frequency (RF) Vehicle and Vessel Stopping systems have known range and overall system size and weight limitations; the current commercial off-the-shelf (COTS) solutions only mitigate a very small portion of the codified JROC-approved long-range vehicle/vessel stopping capability-gap [Refs 1-4]. The intended system is to replace current RF Vehicle/Vessel Stopper technologies with sizes of ~ 160 cu ft and ~1000 pounds and costs of ~\$1M with a prototype wideband-based HPM source/system that is ~ 3 cu ft; 50-100 pounds and costs only \$50-100K; low overall system power consumption of < 25kW of prime power. System must operate commensurate with and compliant with MIL Standard 810H environmental performance/operating standards. See Objective section for specific performance specifications required under this SBIR topic.

Specifically this SBIR topic is seeking wideband (100 MHz to 2 GHz) high power microwave sources with pulse widths of 1 nanosecond (ns) to 200 nanoseconds; pulse repetition frequencies of a few pulses per second to 100 kHz; HPM waveform rise times of 0.25 ns to 100 ns; Electronic Field Strengths of 1kV/meter to 100 kV/meter; polarizations of horizontal or vertical; overall system size and weight of less than 100 lbs (T), 50 lbs (O); and a low overall system cost of <\$100K (T); \$50K (O).

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor must be able to

## VERSION 5

acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and Marine Corps in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

**PHASE I:** Develop concepts for an improved (more compact/lightweight and longer range) broadband/wideband high power microwave (HPM) source to support intermediate force capabilities, i.e., a long-range vehicle and/or vessel engine stopping system.

Demonstrate the feasibility/effectiveness of the wideband HPM source against relevant threat vehicle and vessel engine targets. Collect RF Target Susceptibility data corresponding to the source's RF-HPM waveform against a broad relevant set of (currently available commercial vehicle and vessel engines, e.g., COTS-available threat vehicle and vessel engine) targets. Demonstrate HPM weapon effectiveness and performance in meeting JNLWD/JIFCO/Marine Corps needs and establish that the HPM weapon concept can be employed throughout the Joint Services. Provide a Phase II development plan with performance goals and key technical milestones, and that will address technical risk reduction and define the development of a Phase II non-lethal wideband HPM Vehicle/Vessel Stopping prototype weapon.

PHASE II: Develop a next-generation wideband HPM Vehicle/Vessel Stopping prototype weapon. The prototype will be evaluated via rigorous RF Target Susceptibility testing at both the contractor's facilities and at the Naval Surface Warfare Center - Dahlgren Division (NSWC- Dahlgren) test ranges. The JNLWD-JIFCO maintains a set of relevant threat vehicle and vessel engines at NSWC- Dahlgren. The contractor's Phase II SBIR prototype weapon will be independently assessed and evaluated at these government lab facilities with minimal cost to the performer. The objective of this independent testing is to determine the weapon's capability in meeting the performance goals defined in the Phase II development plan and the Marine Corps requirements for a RF-HPM Vehicle/Vessel Stopper. The full wideband RF-HPM weapons systems to include integration to a high-gain RF-HPM antenna system will be prototyped and tested. System performance will be demonstrated through the evaluation of the HPM weapon system's ability to upset, neutralize, and kill (soft and hard) relevant threat vehicle and vessel engines. Confirm and verify the modeling and analytical methods developed in Phase I to include measuring the required full range of parameters including numerous deployment cycles. Evaluation results will be used to refine the prototype into an initial design that will meet the JIFCO/JNLWD/Marine Corps non-lethal vehicle/vessel stopping requirements. Prepare a Phase III development plan to transition the technology to Joint Service use.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the JIFCO/JNLWD/Marine Corps in transitioning the technology for Joint Service use. Develop this next-generation wideband RF-HPM weapon system for evaluation to determine its effectiveness in an operationally relevant environments, e.g., exercised in Limited Military User Assessments (LMUAs) held by various Services. Support the JIFCO/JNLWD/Marine Corps for test and validation to certify and qualify the system for Joint Service use.

A compact – lightweight long range RF-HPM vehicle/vessel stopping capability has significant commercial applications beyond the DoD. Other government agencies, such as the Department of Justice (DoJ) and the Department of Homeland Security (DHS) to include Customs and Border Patrol, have actively been researching these types of non-lethal counter-electronic effects. Local civilian law enforcement has these type of missions to support both vehicle/vessel interdiction missions as well as to mitigate vehicle/vessel-borne terrorism. Currently overall system size, weight, and cost have hindered the use of these systems by these agencies. This SBIR topic specifically addresses overall system size, weight, power consumption,

## VERSION 5

thermal cooling, and overall system cost all while drastically improving RF-HPM Vehicle/Vessel Stopping weapon performance.

### REFERENCES:

1. Giri, D.V. “High-power Electromagnetic Radiators: Non-Lethal Weapons and Other Applications.” Harvard University Press, 2004. <https://ieeexplore.ieee.org/document/4118005>.
2. Barker, Robert J. and Schamiloglu, Edl. “High-Power Microwave Sources and Technologies: Volume A.” IEEE Press Series on RF and Microwave Technology, Wiley-IEEE Press, Edition 1, June 2001. <https://ieeexplore.ieee.org/book/5265060>.
3. “Directed-energy weapon.” 18 July 2020. [https://en.wikipedia.org/wiki/Directed-energy\\_weapon](https://en.wikipedia.org/wiki/Directed-energy_weapon).
4. Glasmacher, Mathias. “High-Power Electro-Magnetics Effector Systems for Vehicle Stopping.” Diehl Defence Group; Diehl Stiftung & Co, KG, 2020. <https://www.diehl.com/group/en/technology/innovation/hpem/>.

**KEYWORDS:** Wideband High Power Microwave Sources; HPM; Broadband HPM Sources; Mesoband Vehicle/Vessel Stopping; HPM Vehicle/Vessel Stopping technologies; Non-Lethal Counter-Electronic Attack



# VERSION 5

N212-102 TITLE: Portable Hydroelectric Generators

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR);Microelectronics

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a personnel-portable ruggedized hydroelectric generator that will provide power from hydrokinetic water sources and has the ability to be dropped in a stream or other area of moving water and provide a level of power needed to recharge a unit's batteries or meet other low-power requirements.

DESCRIPTION: There is a need within the DoD to reduce the dependence on fossil fuel power generation. Bulk fuel movement is expensive, presents a high safety risk to personnel, and will become less reliable in distributed operations. Renewable energy is one way to reduce costs, increase safety, and provide more reliable power. Unfortunately, renewable energy systems can be heavy, bulky, difficult to deploy, and have a significant footprint during transport and operation and high cost.

The intent of this SBIR topic is to develop a pico-hydro power (micro-hydropower) energy system that is personnel-portable, low volume during transport/operation, efficient, reliable, and cost-effective. The system will be capable of being transported on a vehicle to the hydro resource. It shall be offloaded, carried, and deployed by hand. Water flow and Multi-axes kinetic generation are potential solutions. This SBIR topic seeks innovative scientific and engineering solutions. Proposals should specifically describe the technology that will be applied to solve the problem, how it will be developed, what the estimated benefits will be and how it might be transitioned into the DoD.

Definitions:

System must meet Threshold requirements = (T)

It is highly desirable for the system to meet Objective requirements = (O)

The proposed system must address the following requirements, at a minimum:

1. Capable of producing from 500 W (T) to 1500 W (O) (500W continuous, 5kW peak).
2. Capable of producing 500W using a water flow that has a velocity of 0.5 m/sec (O) or 1 m/sec (T).
3. Operable in rivers or streams with a minimum depth of 0.5 m (O) or 1 m (T).
4. Capable of optimizing electrical power output for any range of water velocities and minimum depths (O).
5. Capable of making use of input water velocity, kinetic energy, or pressure from any direction to generate required and additional electrical power. (O)
6. Component weight of no more than 88 lbs (two-person portable).
7. Total system transport volume/cube not to exceed 1 m<sup>3</sup>, which includes electrical cables, connectors, ropes/tethering/anchoring (if applicable).
8. Ability to meet the requirements of the Marine Corps in all of its operating environments (MIL-STD 810).
9. 24VDC output (MIL-STD-1275D, Ref 3).
10. Operated with little or no human intervention.
11. Capable of repair in the field with plug-and-play line replaceable units or parts produced by expeditionary advanced manufacturing (additive manufactured 3D printed / subtractive manufactured CNC milling or lathing parts).
12. Capable of operation in fresh and brackish water.
13. Able to withstand debris fouling without degrading performance.
14. Capable of being quickly and easily interconnected to produce power in excess of the 500 – 1500 W range of an individual system. (See #1 above.)

## VERSION 5

15. Able to be deployed and operational by 2 people, after reading quick card instructions, within 30 minutes (T), less than 5 minutes (O), starting from its transport configuration.
16. Retrievable and ready for transport within 30 minutes (T), less than 5 minutes (O).

PHASE I: Develop concepts for an improved hydro-electric generator that meets the requirements described above. Demonstrate the feasibility of the concepts in meeting Marine Corps needs. Establish that the concepts can be developed into a useful product for the Marine Corps. Feasibility will be established by material testing and analytical modeling, as appropriate. Provide a Phase II development plan with performance goals and key technical milestones, and that will address technical risk reduction.

PHASE II: Develop a scaled prototype for evaluation to determine its capability in meeting the performance goals defined in the Phase II development plan and the Marine Corps requirements for the hydro-electric generator. Demonstrate system performance through prototype evaluation and modeling or analytical methods over the required range of parameters including numerous deployment cycles. Evaluation results will be used to refine the prototype into an initial design that will meet Marine Corps requirements and develop hydro-electric generator for evaluation to determine its effectiveness in an operationally relevant environment. Prepare a Phase III development plan to transition the technology to Marine Corps use.

PHASE III DUAL USE APPLICATIONS: Support the Marine Corps in transitioning the technology for Marine Corps use. Support the Marine Corps for test and validation to certify and qualify the system for Marine Corps use.

Commercial applications include recreational use, humanitarian aid/disaster relief, and “off-grid” home designs. The recreational industry has seen a significant increase in the last few years specifically with off grid application. This application is directly applicable to this market segment. This recreational market is seen as having the highest potential for commercialization and sales. Support for disaster relief and humanitarian aid are other applications. Additionally, there is application in developing countries and areas underserved by electrical power distribution.

### REFERENCES:

1. Beerman-Curtin, Sharon. “SBIR Topic N112-147: Person-Portable Micro-Hydropower System.” Solicitation 11.2, 2012. [https://www.navysbir.com/n11\\_2/N112-147.htm](https://www.navysbir.com/n11_2/N112-147.htm).
2. “Marine energy - Wave, tidal and other water current converters - Part 300: Electricity producing river energy converters - Power performance assessment. IEC TS 62600-300:2019, 12 September 2019. <https://standards.iteh.ai/catalog/standards/iec/8a96e94d-2e9a-4597-b14e-74749352eb54/iec-ts-62600-300-2019>.
3. “Marine energy - Wave, tidal and other water current converters - Part 301: River energy resource assessment.” IEC TS 62600-301:2019, 12 September 2019. <https://tc114.us/standards-development/purchase-iec-tc-114-documents/>.
4. Lambert, Brent. “Check Out the Incredible New Portable Air Conditioner & Underwater Turbine Powered River Current.” FEELGuide, 9 September 2019. <https://www.feelguide.com/2019/09/09/check-out-the-incredible-new-portable-air-conditioner-underwater-turbine-powered-by-river-current/>.
5. Office of Energy Efficiency & Renewable Energy. “WPTO Announces \$4.4 Million for Phase I Small Business Innovation Projects.” 21 May 2020. <https://www.energy.gov/eere/water/articles/wpto-announces-44-million-phase-i-small-business-innovation-projects>.
6. Naval Sea Systems Command. “2019 Naval Power & Energy Systems Technology Development Roadmap: Energy Harvesting.” [https://www.navsea.navy.mil/Portals/103/Documents/2019\\_NPES\\_TDR\\_Distribution\\_A\\_Approved\\_Final.pdf?ver=2019-06-26-132556-223](https://www.navsea.navy.mil/Portals/103/Documents/2019_NPES_TDR_Distribution_A_Approved_Final.pdf?ver=2019-06-26-132556-223).

## VERSION 5

7. "Underwater Turbines." Pioneer Valley Renewables, LLC. 13 July 2020  
<http://pioneervalleyrenewables.com/>.

KEYWORDS: Hydropower; hydro-electricity; pico-hydro; portable; turbine; micro-hydro; renewable

# VERSION 5

N212-103 TITLE: Multispectral Target and Scene Projector

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Design and develop a multispectral scene projector capable of presenting a scene to a gimbaled sensor under test.

**DESCRIPTION:** The U.S. Navy currently operates a number of legacy spectral scene generators to test a number of single and dual band sensors. The background comprises a Visible (VIS) band projected onto a blocking target that is opaque to all VIS wavelengths, prior to entering a collimating optic and presented to the gimbaled sensor. A number of blocking targets with various angular sizes exist on a filter wheel allowing the system to characterize sensor resolution.

A target beam, maintained at the center of the scene, represents the Mid-Wave Infrared (MWIR) signature of an air platform, generated by an IR source with an aperture to control angular extent and a variable Neutral Density (ND) filter to rapidly change intensity. These two collimated sources, the MWIR target and VIS background, are combined by an optic with the MWIR target aligned to the collimated blocked portion of the background. Finally, a pickoff mirror allows 90% of the combined beam to pass to the sensor under test, while reflecting 10% toward a camera used for scene awareness.

The scene projected and presented to the sensor under test is comprised of a collimated background of VIS light, a negative target of blocked VIS light with MWIR superimposed on the negative target.

This is a simplistic static system allowing for investigation of target resolution and sensor sensitivity. However, this system lacks the required dynamics of other targets in the scene, required for investigating tracking algorithms.

This SBIR topic is seeking to extend the technology of legacy generators by adding additional targets with the ability to move within the scene and change their spectral content. An example scene may comprise a mixture of Ultra-Violet (UV)/VIS intensities as a background; a static target that blocks the background but retains a signature with Long Wave Infrared (LWIR), MWIR, Short-Wave Infrared (SWIR), VIS, and UV components; and three other moving dynamic targets comprised of a mixture of LWIR, SWIR, MWIR, VIS, and UV emissions.

This system will evaluate a gimbaled sensor and the performance of tracking algorithms in a spectrally complex environment having dynamic targets with signatures comprised of LWIR, MWIR, SWIR, VIS, and UV bands, combined with an illuminated background emitting in the UV and/or VIS bands (Ref 5). This system should reside on one or two optical tables in which the scene is generated and allow for positioning the sensor under test.

## VERSION 5

The background presented to the sensor under test must provide an illuminated background emitting in the UV and/or VIS bands. The background represents the sky as seen by a sensor. The sensor under test will typically be banded, but that defined band may be anywhere from the UV to VIS portions of the spectrum. The intensity of the background should have a comparable intensity to that of the sky and be adjustable to simulate differing intensities, such as a sunny day, overcast, and heavy cloud cover; as well as time of day, such as morning, noon, and evening.

The bands described in this document are defined as follows:

- a. UV: 300-400 nm
- b. VIS: 400-700 nm
- c. SWIR: 1-3  $\mu\text{m}$
- d. MWIR 3-5  $\mu\text{m}$
- e. LWIR: 8-12  $\mu\text{m}$

A single primary target source represents an air-platform in a scene as a spot, blocking the UV and VIS portions of the background as an aircraft traveling across the sky. However, while blocking the background, the Primary Target may be emitting in any of the UV, VIS, SWIR or MWIR, and LWIR bands and overlay on the blocked spot. The mixture of bands, angular extent, and intensities must be variable as a function of time to simulate platforms operating at different ranges at different headings.

The secondary targets represent other emitters in the spectrally rich scene such as other air-platforms, munitions, or countermeasures. These sources have variable intensities and emit in the UV, VIS, SWIR, MWIR, and LWIR bands. However, these sources do not block the UV and VIS emissions of the background. These sources must also have the ability to vary the mixture of LWIR, SWIR, MWIR, VIS, and UV emissions, intensities in each band, angular size, and following a pre-programmed trajectory, dynamically move in relation to the primary target. The projector should present three or four secondary targets.

There is a requirement to provide awareness of the scene presented to the sensor under test, in real time, as the scene develops. This imagery output is used to create a data product that overlays a sensor's gimbaled track-point on the scene as it develops. For more simplistic projectors involving only two adjacent bands, a beam splitter is used to capture a portion of the energy and present it to a camera. This is a more difficult problem since a single camera cannot capture the spectral data across the spectrum and will require multiple cameras, each with a fused spectral output. Just as in the legacy system, a camera(s) must capture and display the scene presented to the sensor under test.

Software is required to control the many elements of the scene projector and has two main functions. First is designing and planning the scene as it evolves in time, including the spectral content, intensities of the different bands, angular size, and motion of each source. The second function is the control of the optical components as the test occurs.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances. This will allow contractor personnel to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

# VERSION 5

PHASE I: Develop, design, and demonstrate the feasibility to build a scene projector, employing beam combining/mixing optics that have previously been built, combining two neighboring spectral bands such as MWIR and SWIR, and methods for controlling the motion in the scene, including moving combining mirrors and sending the image into a collimating optic. The Phase I demonstration will include prototype plans to be developed under Phase II.

PHASE II: Develop a prototype multispectral scene projector capable of presenting a scene to a gimbaled sensor under test. Provide schematic and layout of optics, emitters and other components. Develop a method for viewing the entire scene in all bands presented to the sensor. Develop a controlling Graphical User Interface (GUI) and identify variables. Demonstrating the multispectral projector is capable of giving similar results to more simplistic legacy system, while considering radiometric measurement of spectral components of the scene.

It is probable that the work under this effort, particularly in the sensor portion, will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Finalize the prototype and provide demonstration of the multispectral projector on an advanced sensor. Perform final testing and validation. Transition to applicable naval platforms and/or naval laboratories.

The multispectral scene generator will be suitable for testing hardware-in-the-loop systems incorporating multiple sensors across multiple EO/IR bands, such as missile seekers, ISR camera systems, and targeting systems. The scene projector will also provide a critical laboratory-based pathway for the development of EO/IR algorithms employing sensor fusion and the merging of information across multiple bands to achieve increased accuracy. Industries include Intelligence, Surveillance and Reconnaissance (ISR), and Missile Defense.

## REFERENCES:

1. Jennison, P. J., Tritchew, S., Johnston, F., Demers, L. and Trottier, G. "The infra redtarget generator (IRTG)." Proceedings of SPIE 1110, Imaging infrared: scene simulation, modeling, and real image tracking, September 20, 1989. <https://doi.org/10.1117/12.960749>.
2. Pinsky, E. and Sturlesi, D. "Generation of dynamic IR scene for seekers testing." Proceedings of SPIE 3061, Infrared technology and applications XXIII, August 13, 1997 <https://doi.org/10.1117/12.280388>.
3. Nelson, N. R., Bryant, P. T. and Sundberg, R. L. "Development of a hyperspectral scene generator." Proceedings of SPIE 5151, Earth observing systems VIII, November 10, 2003. <https://doi.org/10.1117/12.506376>.
4. Sturlesi, D. and Pinsky, E. "Target scene generator (TSG) for infrared seeker evaluation." Proceedings of SPIE 3084, Technologies for synthetic environments: hardware-in-the-loop testing II, July 15, 1997. <https://doi.org/10.1117/12.280941>.
5. Ashley, G. W., Jr., Buenting, E. O., Leonard, C. A. and Lessman, G. "Dual spectral range target tracking seeker. (U.S. Patent No. 4,009,393)." U. S. Patent and Trademark Office, 1977. <https://pdfpiw.uspto.gov/.piw?Docid=4009393&idkey=NONE&homeurl=http%3A%252F%252Fpatft.uspto.gov%252Fnethtml%252FPTO%252Fpatimg.htm>.

KEYWORDS: Scene Projector; Target Projector; Sensors; Spectral; Multispectral; Missile Seeker



# VERSION 5

N212-104      TITLE: Multimode-Coupled High-Frequency Photoreceiver

RT&L FOCUS AREA(S): Autonomy;General Warfighting Requirements (GWR);Networked C3

TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop and package a multimode, pigtailed, high-frequency, high-current, optical photodetector operating at a wavelength near 1.5  $\mu\text{m}$  for radio-frequency (RF) photonic link applications on military platforms.

**DESCRIPTION:** Current airborne military communications and electronic warfare systems require ever-increasing bandwidth, while simultaneously requiring reductions in space, weight, and power (SWaP). The replacement of the coaxial cable used in various onboard radio frequency (RF)/analog applications with RF/analog fiber-optic links will provide increased immunity to electromagnetic interference, reduction in size and weight, and an increase in bandwidth. However, it requires the development of high-performance, high-linearity optoelectronic components that can meet extended temperature range requirements (-40 °C to 100 °C). Additionally, avionic platforms pose stringent requirements on the SWaP consumption of components for avionic fiber communications applications [Ref 4]. To meet these requirements, new optical component technology will need to be developed.

Typical microwave photonic links for 20 GHz and higher frequencies utilize single-mode fiber between transmitter and receiver. Single-mode fiber eliminates modal dispersion associated with multimode fiber, which reduces bandwidth in long fiber lengths [Ref 1]. Many links on airborne platforms however are short in length and can utilize multimode fiber, yielding installation, maintenance, and durability advantages. A standard 50  $\mu\text{m}$  core multimode fiber is easily coupled to photodiodes larger than 50  $\mu\text{m}$  in diameter, but 50  $\mu\text{m}$  photodiodes are limited to bandwidths below 20 GHz due to capacitive limitations. If the light from a 50  $\mu\text{m}$  multimode fiber could be focused onto high-current photodiodes with diameters of 25, 15, or even 10  $\mu\text{m}$  using a high-numerical aperture optical system [Ref 2], while still capturing a majority of the light in the fiber, link bandwidths can be pushed to over 50 GHz. With a typical 1 GHz-Km graded index 50  $\mu\text{m}$  fiber, this allows for link lengths upwards of 50 and 20 m at 20 and 50 GHz, respectively, when all modes contain energy. This will negate standard butt-coupling approaches and will require optical lenses to be utilized with higher numerical apertures. This, combined with the fact that many high-current photodiodes are rear illuminated through the substrate, leads to long optical path lengths, a challenge for compact packaging. One additional challenge is the speckle pattern that will appear within the image of the output of the fiber on the photodiode surface. If too large of a fraction of this reduced image falls outside the photodiode active area, speckle variations will result in variations in the detected photocurrent that will be unavoidable and cause deleterious link gain variations. These current variations must be kept below +/- 5% to limit link gain variations to +/- 0.5 dB.

The packaged photoreceiver must perform over the specified temperature range and maintain hermeticity and optical alignment upon exposure to typical Navy air platform vibration, humidity, thermal shock, mechanical shock, and temperature cycling environments [Ref 3], and which can include unpressurized

# VERSION 5

wingtip or landing gear wheel well (with no environmental control) to an avionics bay (with environmental control).

PHASE I: Develop, demonstrate feasibility, and package (non-hermetic) a sub-35  $\mu\text{m}$  diameter photodiode ( $> 12$  GHz bandwidth) with a 50  $\mu\text{m}$  graded-index multimode fiber pigtail. The detected photocurrent should maintain  $\pm 5\%$  current variation as the input modal pattern is varied. Provide calculations to support the development of 20, 35, and 50 GHz versions for development during Phase II. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop a prototype design and package hermetic prototypes at 15, 20, 35, and 50 GHz. Test prototype receivers to meet the above photocurrent variation specification over input modal conditions, and over temperature, to meet design specifications in a Navy air platform representative of a relevant application environment, which can include unpressurized wingtip or landing gear wheel well (with no environmental control) to an avionics bay (with environmental control). The packaged receivers should be tested in an RF photonic link over temperature with the objective performance levels reached. Demonstrate a prototype fully packaged receiver for direct insertion into analog fiber optic links.

PHASE III DUAL USE APPLICATIONS: Finalize the prototype. Perform extensive operational reliability and durability testing, while optimizing manufacturing capabilities. Transition the demonstrated technology to naval aviation platforms and interested commercial applications.

Commercial sector telecommunication systems, fiber optic networks, and data centers could benefit from the development of a Multimode Coupled High Frequency Photoreceiver.

## REFERENCES:

1. Agrawal, G. "Fiber-optic communication systems (4th ed.)." John Wiley & Sons, 2010. <https://books.google.com/books?hl=en&lr=&id=yGQ4n1-r2eQC&oi=fnd&pg=PR15&dq=Fiber-optic+communication+systems+&ots=PYFbM1hFlq&sig=iqLoAJCdW3hwt5Tgxsc1RHoInW4#v=onepage&q=Fiber-optic%20communication%20systems&f=false>.
2. Saleh, B. E. and Teich, M. C. "Fundamentals of photonics." John Wiley & Sons, 2019. <https://books.google.com/books?hl=en&lr=&id=rcqKDwAAQBAJ&oi=fnd&pg=PR1&dq=Fundamentals+of+Photonics&ots=tGkk82ECw1&sig=j16xAcEUJEvtT7OAqySCwBLZrDo#v=onepage&q=Fundamentals%20of%20Photonics&f=false>.
3. "MIL-STD-810H, Department of Defense test method standard: Environmental engineering considerations and laboratory tests." Department of Defense, US Army Test and Evaluation Command, January 31, 2019. [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H\\_55998/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/).
4. "RTCA DO-160G - Environmental Conditions and Test Procedures for Airborne Equipment, December 16, 2014." Radio Technical Commission for Aeronautics. <https://do160.org/rtca-do-160g/>.

KEYWORDS: Photodetector; Photodiode; Radio Frequency; Wideband; Fiber Optic; Multimode.

# VERSION 5

N212-105 TITLE: Zero Foreign Object Damage (FOD): Inlet Debris Monitoring System (IDMS)

RT&L FOCUS AREA(S): Artificial Intelligence (AI)/Machine Learning (ML);Autonomy

TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Design an Inlet Debris Monitoring System (IDMS) to detect when jet engines ingest Foreign Object Damage (FOD) [Ref 1] and quantify its sensitivity to typical Navy/Marine Corps flight and environmental operating conditions.

**DESCRIPTION:** Foreign Object Damage (FOD) is a top engine removal driver for nearly every platform in naval aviation. Debris ingestion causes unacceptable readiness and safety levels for a variety of fixed- and rotary-wing platforms. FOD is responsible for seven Class A mishaps (i.e., an accident that leads to fatality, dismemberment, or greater than \$2 million in damages) (Ref 4) and cost the Naval Aviation Enterprise (NAE) over \$400 million in the past three years. The FOD Program, which applies research to understand, quantify, and prescribe solutions to FOD that require coordination across commands and installations, projects FOD will cost the NAE > \$2 billion over the next five years.

The FOD Program is developing a method for synthesizing and analyzing data from novel sensing technologies to quantify the risk of operating aircraft in an environment with a dynamic debris field. The prototype, known as the FOD System-of-Systems Approach (SOSA), enables the integration of multiple sensor suites, data logistics, data fusion, data analysis, and automation. The purpose of the FOD system is to calculate and remediate the risk of engine FOD strikes.

The FOD Program requires an on-wing, Inlet Debris Monitoring System (IDMS) capable of detecting when an engine ingests debris and particulate. The IDMS will act as feedback to the FOD SOSA to continually refine the FOD SOSA's predictive analytical capability and improve the FOD SOSA's ability to reduce FOD events.

Topic requirements include, but are not limited to:

1. The design and build of a flight qualified prototype IDMS
2. An established system interface and interface control document (ICD) for the IDMS
3. Determination of which factors limit or affect its Probability of Detection (Pd) and Probability of False Alarm (Pfa)
4. Quantification of how those factors limit or affect its Pd and Pfa
5. A mathematical model to represent the IDMS's Pd and Pfa as a function of IDMS configurable elements, environmental conditions, and FOD related variables.

Flight and environmental conditions an IDMS may experience, and thus affect a Pd and Pfa, include (\*Note the following conditions are not a comprehensive list of factors):

1. Operationally relevant environmental factors (Ref 2):
  - (a) Temperature

## VERSION 5

- (b) Temperature distortion (steam ingestion)
- (c) Humidity
- (d) Rain
- (e) Snow
- (f) Ice
- (g) Fog
- (h) High and Low ambient light conditions
- (i) Non-uniform airflow
- (j) Dusty/Sandy conditions
- (k) Non-pristine airflow consisting of oil, insects, etc. which deposit on airflow boundaries
- 2. Operationally representative inlet velocities at all phases of the flight envelope:
  - (a) Ground maneuvers
  - (b) Takeoff/Descent maneuvers
  - (c) Flight maneuvers
- 3. Operationally representative flight noise [Ref 3]:
  - (a) General aircraft noise
  - (b) Vibrations
  - (c) Acoustics
  - (d) Electromagnetic Interferences

Common examples of discrete events, consisting of both hard and soft debris, include (\*Note the following materials are not a comprehensive list of FOD):

- (a) Sand
- (b) Bolts
- (c) Nuts
- (d) Concrete
- (e) Carrier decking material
- (f) Lock wire
- (g) Pavement
- (h) Plastic
- (i) Cloth
- (j) Organics

A Minimum Viable Product (MVP) of an IDMS should be flight qualified and integrated into at least one test aircraft and possess the ability to:

1. Demonstrate the sensitivity of the IDMS prototype to detect a FOD event in a relevant Navy/Marine Corps environment that includes:
  - (a) Quantifiable Pd and Pfa of the prototype
  - (b) Identify factors that affect the Pd and Pfa
  - (c) Degree that each factor affects the Pd and Pfa
2. Detect when an engine ingests debris during conditions typical of Navy/Marine Corp idle, taxi, take-off, and landing (these include inlet velocities of 0–600 ft/s (0–183 m/s)
  - (a) Produce a time stamped data log indicating when an engine ingests debris
  - (b) Tag the timestamped data log with where the engine ingests debris; for example, land-based operations could include GPS coordinates while ship-based operations could include a location on the carrier deck (the IDMS may use external data sources to achieve this objective)
3. Integrate with the FOD Program's SOSA
4. Possess well-defined system interfaces with an interface control document

# VERSION 5

The IDMS should:

1. Integrate with other inlet debris monitoring technologies.
2. Quantify details of the FOD event such as:
  - (a) The physical attributes of the debris such as its type, volume, mass, density, material composition, etc.
  - (b) The velocity of the debris
  - (c) Where, within the engine, the debris strikes and/or damages
3. Operate in all areas of the flight envelope. Detect when an engine ingests debris during typical Navy/Marine Corp flight (an MVP already includes idle, taxi, take-off, and landing).
4. Be capable of optimizing along the following parameters:
  - (a) Adaptability/Modularity: The system should be able to integrate into various military and commercial aircraft.
  - (b) Spatial Footprint: The system should fit within an engine/airframe.
  - (c) Maintainability: Maintainers should be able to access and maintain the IDMS
  - (d) Robustness: The IDMS should not fail and create FOD itself.
  - (e) Safety: The IDMS should not pose a safety risk to people, including pilots, maintainers, airfield personnel, bystanders, etc.

PHASE I: Demonstrate the feasibility of the technology through a series of Technology Readiness Level (TRL) maturation events. Demonstrate the technology's basic scientific principles. Demonstrate the feasibility of applying the technology to an IDMS by designing, testing, and validating a basic breadboard laboratory experiment. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop, demonstrate, and validate the breadboard and test it in an environment that represents the speed and particulate size/material typical of a Navy/Marine Corps environment; begin studying Pd and Pfa.

Produce a prototype system that consolidates the breadboard into an operationally representative IDMS configuration; increase the testing rigor to include representative mechanical effects such as engine acoustics and vibrations and aerodynamic effects such as temperature, pressure, and non-uniform airflow. Characterize the prototype's performance when exposed to these mechanical and aerodynamic effects.

Refine the prototype to be worthy of flight qualification. Quantify the Pd and Pfa under varying operational and environmental conditions (see Description section for details) before exiting this stage and the IDMS does not pose a safety of flight risk to an aircraft.

PHASE III DUAL USE APPLICATIONS: Finalize the prototype for a selected Navy and/or Marine Corps aircraft. Integrate the prototype into the select aircraft and the SOSA. Support flight-testing. Work to enable the retrofit of operational aircraft with the IDMS.

FOD costs the commercial aviation industry over \$2 billion per year [Ref 4] and an average of \$43 million per year at major U.S. hubs. The FOD Program projects that the FOD SOSA's risk remediation techniques, enabled by the IDMS subject to this topic, will increase commercial aircraft availability by between 15 and 30 aircraft per airfield per year and reduce cost of ownership for airlines by between \$20 million and \$50 million per airfield per year where the SOSA is operational.

## REFERENCES:

1. "FOD education: What is FOD?" The FOD Control Corporation (n.d.). <https://www.fodcontrol.com/what-is-fod/#:~:text=What%20is%20FOD%3F%201%20Foreign%20Object%20Debris%E2%80%A6%20Foreign,Facilities.%20...%205%20Sources%20for%20more%20information.%20%3E>.

## VERSION 5

2. “MIL-HDBK-310, Military handbook: Global climatic data for developing military products.” United States Department of Defense, June 23, 1997. [http://everyspec.com/MIL-HDBK/MIL-HDBK-0300-0499/MIL\\_HDBK\\_310\\_1851/](http://everyspec.com/MIL-HDBK/MIL-HDBK-0300-0499/MIL_HDBK_310_1851/).
3. “MIL-STD-810H, Department of Defense test method standard: Environmental engineering considerations and laboratory tests.” United States Department of Defense, MIL STD 810 Working Group, January 31, 2019. [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H\\_55998/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/).
4. Reference updated 04/28/2021 – FOD Drone Habitat and Safety (FDHS) Series Brief, March 21, 2021 [https://navysbir.com/n21\\_2/N212-105\\_Reference\\_4\\_FDHS\\_Brief.pdf](https://navysbir.com/n21_2/N212-105_Reference_4_FDHS_Brief.pdf)

KEYWORDS: FOD; IDMS; PHM; CBM; EHM; SOSA; Inlet Debris Monitoring System; Foreign Object Damage; Probability of Detection; Pd; Probability of False Alarm; Pfa



# VERSION 5

N212-106 TITLE: Fast Low Loss Uninterrupted Optical Switch

RT&L FOCUS AREA(S): Autonomy;General Warfighting Requirements (GWR);Networked C3

TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop and package a 2 x 2 single mode optical switch operating at 1.55  $\mu\text{m}$  wavelength capable of switching speeds below 1  $\mu\text{s}$  with a directivity of 50 dB and an excess loss of less than 1.0 dB with a continuous intensity change from port-to-port.

**DESCRIPTION:** Current airborne military communications and electronic warfare systems require ever increasing bandwidths while simultaneously requiring reductions in size, weight, and power (SWaP). The replacement of the coaxial cable used in various onboard Radio Frequency (RF)/analog applications with RF/analog fiber optic links will provide increased immunity to electromagnetic interference, reduction in size and weight, and an increase in bandwidth. However, routing these signals to different locations within the airframe with high efficiency, or for routing/reconfiguring within the front end of an RF processor, requires the development of low-loss optical switches that can meet extended temperature range requirements (-40  $^{\circ}\text{C}$  to 100  $^{\circ}\text{C}$ ). Additionally, avionic platforms pose stringent requirements on the SWaP consumption of components for avionic fiber communications applications. To meet these requirements, new optical component technology will need to be developed.

Typical microwave photonic links for 20 GHz and higher frequencies utilize single-mode fiber between transmitter and receiver. Many antennas on airborne platforms will be required to send their signals to a plurality of RF processors at different locations on the platform, which will require low-loss optical switching devices. In addition, for some RF front ends and processors, re-configurability in the front end is needed that will require optical path reconfiguration. Optical switches for these applications require continuous power transfer from two inputs to two outputs with continuous optical connectivity (without dead time) so RF information is not lost during the switching process. Switching speed will also need to be below 1.55  $\mu\text{s}$  for these applications to minimize the transition time. Electro-optic [Ref 1] or magneto-optic technologies [Ref 2] offer the potential for fast switching if optical losses can be minimized. Other technologies, including integrated photonics platforms, may also be promising so long as the above specifications are met.

The packaged 2 x 2 optical switch in single, dual, and quad switch packages must perform over the specified temperature range and maintain hermeticity and optical alignment upon exposure to typical Navy air platform vibration, humidity, thermal shock, mechanical shock, and temperature cycling environments [Refs 3, 4], which can include unpressurized wingtip or landing gear wheel well (with no environmental control) to an avionics bay (with environmental control).

**PHASE I:** Demonstrate the feasibility of a 2-input, 2-output 1.55  $\mu\text{m}$  optical switch that can switch at microsecond or better speeds. The switch must be capable of continuously variable coupling ratios between the two inputs/outputs so that no dead time results during switching. Provide detailed design and packaging

## VERSION 5

plan to support the development during Phase II. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Optimize Phase I design, develop, and package prototype 2 x 2 switches in single, dual, and quad switch packages. Test prototype switches to meet the loss and switching speed specifications over temperature to meet design specifications in a Navy air platform representative of a relevant application environment, which can include unpressurized wingtip or landing gear wheel well (with no environmental control) to an avionics bay (with environmental control). Demonstrate a prototype fully packaged switch for direct insertion into single-mode analog fiber optic links.

PHASE III DUAL USE APPLICATIONS: Finalize the prototype. Perform extensive operational reliability and durability testing, as well as optimize manufacturing capabilities. Transition the demonstrated technology to naval aviation platforms and interested commercial applications.

Commercial sector data centers, industries utilizing local area networks and telecommunication systems, as well as companies that install networks and telecommunications systems would benefit from the development of this fast, low-loss, uninterrupted optical switch technology.

### REFERENCES:

1. Kaur, S., Singh, M., Singh, H. and Singh, M. L. "Design and Performance Analysis of 2x2 electro-optic based MZI switch using Ti: LiNbO<sub>3</sub> as a waveguide at 1.46  $\mu\text{m}$ ." 2019 IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), February 2019, pp. 1-5. <https://doi.org/10.1109/ICECCT.2019.8869376>.
2. Bahuguna, R., Mina, M., Tioh, J. W. and Weber, R. J. "Magneto-optic-based fiber switch for optical communications." IEEE transactions on magnetics, 42(10), 2006, pp. 3099-3101. <https://doi.org/10.1109/TMAG.2006.878870>.
3. "MIL-STD-810H, Department of Defense test method standard: Environmental engineering considerations and laboratory tests." Department of Defense, US Army Test and Evaluation Command, January 31, 2019. [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H\\_55998/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/).
4. Verification of Discrete and Packaged Photonic Device Technology Readiness: ARP 6318." <https://www.sae.org/standards/content/arp6318/>.

KEYWORDS: Optical Switch; Fiber Optic; Single Mode; Dead Time; Switching Speed; uninterrupted

# VERSION 5

N212-107      TITLE: Novel Feedstock Production System for Metallic Additive Manufactured Structural Parts and Repairs

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platforms;Materials / Processes;Weapons

OBJECTIVE: Develop a novel low-cost, high-yield metallic-powder production system capable of rapidly producing small batches (i.e., tens of grams to hundreds of kilograms) of feedstock for Additive Manufactured (AM) structural parts and repairs.

DESCRIPTION: Current production systems are capital and labor intensive, making the powders inordinately expensive, especially for small batches. The AM powders are also very costly with limited availability due to low yield and the needs for specific, high-quality, narrow particle size distributions (PSD) that are optimal for each AM process. For instance, the powder particles are usually specified with a size range of 15-45  $\mu\text{m}$  diameter (dia.) for Laser Beam Melted (LBM)/Powder Bed Fusion (PBF) process, 45-106  $\mu\text{m}$  dia. for Electron Beaming Melting (EBM)/PBF, and 45-75  $\mu\text{m}$  dia. for Directed Energy Deposition (DED)/Laser Engineered Net Shaping (LENS).

In the academic and research arena, the lack of willing powder producers, long lead time, and high cost for low-quantity orders severely hinder the ability to rapidly validate and optimize the chemical compositions, microstructures, and mechanical performance for various material designs. To accelerate the performance optimization and verification of new alloy designs, high-quality feedstock in affordable small batches needs to be readily obtained for build trials.

As AM is adopted by more and more manufacturers, part designs will become more diversified and customized. There will be lower manufacturing volume of custom designed parts and assemblies as compared to the traditional mass production. A similar trend will also develop for new alloys used for different future applications. There will be more demand for alloys that are specifically designed for specific applications and less for standard alloys. This will drive the production of feedstock toward smaller scales and perhaps distributed where it is needed.

In the Maintenance, Repair and Overhaul (MRO), and fleet sustainment communities, the availability of small quantity supply with short-turnaround time without the needs for provisioning and storage is essential for timely part replacement and repairs.

A low-cost, small-batch, high-yield feedstock production system for AM processing is required. The targeted cost for a production unit should be in the range of \$10K's to low \$100K's. The system must be user-friendly, and provide sufficient adjustable controls, coupled with integrated internal monitoring sensors, to assure consistent and uniform high-quality powders (Refs. 10-13) (e.g., particle size distribution, sphericity, internal porosity, surface roughness, oxygen level, amount of satellite particles that adhere to spherical powders, flowability). It must also be capable of making high-yield (50% or greater), small batches (tens of grams to hundreds of kilograms) of traditional metallic powders (e.g., Ti64, 17-4PH SS, IN718, AlSi10Mg), as well as specialty designed alloys. Integrated Computational Material Engineering (ICME)-based modeling & simulation (M & S) of the powder fabrication process should be utilized to support the system design and development.

PHASE I: Develop and design a low-cost, small-batch, high-yield powder production system for metal AM applications. Perform system design, M & S, and associated experimental testing to validate the concept (Refs. 14 & 15). Generate preliminary performance and system specifications for the proposed design

## VERSION 5

including powder handling, storage, and disposal procedures. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop, design and prototype a complete powder production system for AM applications. Demonstrate that the metallic powders can be successfully used for AM of aircraft components. Update performance and system specifications and special handling procedures including powder handling, storage, and disposal procedures.

PHASE III DUAL USE APPLICATIONS: Conduct final system checkout and acceptance testing. Perform production demonstration for multiple types of materials and alloys. Finalize performance and system specifications and special handling procedures.

This topic has a great and widespread potential benefit to commercial sectors ranging from academic research arena to the automobile industry.

### REFERENCES:

1. Dietrich, S., Wunderer, M., Huissel, A. and Zaeh, M. F. "A new approach for a flexible powder production for additive manufacturing." *Procedia Manufacturing*, Vol. 6, 2016, pp. 88-95. <https://doi.org/10.1016/j.promfg.2016.11.012>.
2. Anderson, I. E., White, E. M. H. and Dehoff, R. "Feedstock powder processing research needs for additive manufacturing development." *Current Opinion in Solid State and Materials Science*, 22(1), February 2018, pp. 8-15. <https://doi.org/10.1016/j.cossms.2018.01.002>.
3. Kotlyarov, V. I., Beshkarev, V. T., Kartsev, V. E., Ivanov, V. V., Gasanov, A. A., Yuzhakova, E. A., Samokhin, A. V., Fadeev, A. A., Alekseev, N. V., Sinayskiy, M. A. and Tretyakov, E. V. "Production of spherical powders on the basis of group IV metals for additive manufacturing." *Inorganic Materials: Applied Research*, 8(3), 2017, pp. 452-458. <https://doi.org/10.1134/S2075113317030157>.
4. Sun, P., Fang, Z. Z., Zhang, Y. and Xia, Y. "Review of the methods for production of spherical Ti and Ti alloy powder." *Journal of The Minerals, Metals & Materials Society (JOM)*, 69(10), August 15, 2017, pp. 1853-1860. <https://doi.org/10.1007/s11837-017-2513-5>.
5. Sungkhaphaitoon, P., Plookphol, T and Wisutmethangoon, S. "Design and development of a centrifugal atomizer for producing zinc metal powder." *International Journal of Applied Physics and Mathematics*, 2(2), 2012, pp. 77-82. <https://doi.org/10.7763/IJAPM.2012.V2.58>.
6. Yang, S., Gwak, J. N., Lim, T. S., Kim, Y. J. and Yun, J. Y. "Preparation of spherical titanium powders from polygonal titanium hydride powders by radio frequency plasma treatment." *Materials Transactions*, 54(12), 2013, pp. 2313-2316. <https://doi.org/10.2320/matertrans.M2013329>.
7. Backmark, U., Backstrom, N. and Arnberg, L. "Production of Metal Powder by Ultrasonic Gas Atomization." (Retroactive Coverage). *Powder Metallurgy International*, 18(6), pp. 422-424.
8. Kumar, M. and Pandey, A. B. "Ultrasonic Gas Atomization: Pros and Cons." *Key Engineering Materials*, Vol. 29, 1988, pp. 1-8. <https://doi.org/10.4028/www.scientific.net/KEM.29-31.1>.
9. Clyne, T. W., Ricks, R. A. and Goodhew, P. J. "The production of rapidly-solidified aluminum powder by ultrasonic gas atomization." *Heat and Fluid-Flow. International Journal of Rapid Solidification*, 1(1), January 1984, pp. 59-80. [https://www.researchgate.net/publication/280139600\\_PRODUCTION\\_OF\\_RAPIDLY-SOLIDIFIED\\_ALUMINIUM\\_POWDER\\_BY\\_ULTRASONIC\\_GAS\\_ATOMIZATION\\_PART\\_I\\_HEAT\\_AND\\_FLUID\\_FLOW](https://www.researchgate.net/publication/280139600_PRODUCTION_OF_RAPIDLY-SOLIDIFIED_ALUMINIUM_POWDER_BY_ULTRASONIC_GAS_ATOMIZATION_PART_I_HEAT_AND_FLUID_FLOW).
10. SAE AMS7002 Process Requirements for Production of Metal Powder Feedstock for Use in Additive Manufacturing of Aerospace Parts, [www.sae.org](http://www.sae.org).
11. ASTM F2924-14, Standard Specification for Additive Manufacturing Titanium-6 Aluminum-4 Vanadium with Powder Bed Fusion, ASTM International, West Conshohocken, PA, 2014, [www.astm.org](http://www.astm.org).

## VERSION 5

12. ASTM F3184-16, Standard Specification for Additive Manufacturing Stainless Steel Alloy (UNS S31603) with Powder Bed Fusion, ASTM International, West Conshohocken, PA, 2016, [www.astm.org](http://www.astm.org).
13. ASTM F3055-14a, Standard Specification for Additive Manufacturing Nickel Alloy (UNS N07718) with Powder Bed Fusion, ASTM International, West Conshohocken, PA, 2014, [www.astm.org](http://www.astm.org).
14. ASTM F3049-14, Standard Guide for Characterizing Properties of Metal Powders Used for Additive Manufacturing Processes, ASTM International, West Conshohocken, PA, 2014, [www.astm.org](http://www.astm.org).
15. ASTM F3318-18, Standard for Additive Manufacturing – Finished Part Properties – Specification for AlSi10Mg with Powder Bed Fusion – Laser Beam, ASTM International, West Conshohocken, PA, 2018, [www.astm.org](http://www.astm.org).

KEYWORDS: Additive Manufacturing; Powders; Metals; Feedstock Production; Small Batch

## VERSION 5

N212-108      TITLE: Low-Inclusion Content for High-Grade Steel Material Used in Gear-and-Bearing Components

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Design and develop a steel processing method to dramatically reduce the inclusion content of steel bar stock for current gear material X-53 double vacuum melt (AMS 6308) beyond levels currently available commercially in steel intended for use in aerospace-level gear-and-bearing components.

**DESCRIPTION:** The naval aviation community, as owner and operator of aerospace systems, continuously seeks improvement in the manufacturing arena. The Navy occasionally faces issues with inclusions in aerospace components made from the current gear material X-53 double vacuum melt (AMS 6308). Developing a cost-neutral manufacturing technology that would allow higher grade steel material with dramatically lower inclusion content would increase fatigue life, improve safety, and lower sustainment costs for a steel component. The goal is a lower inclusion content level of 90% objective (75% threshold) than is documented in the current inclusion standard in the material standard AMS 6308. This would result in a decrease in cost to the Government and/or original equipment manufacturers (OEMs), while improving homogenous performance of the material in production creation of components and use of those components. Transmission components, such as gears and bearings, are made from steel in the 4 to 14 inch diameter bar sizes. Determination of the size, type, distribution, and location of inclusions within the created material is the desired output. Comparison to current gear material X-53 double vacuum melt with ASTM E45 inspection standard is required to verify improvement.

**PHASE I:** Develop, design, and demonstrate feasibility of an analytical concept of technology allowing lower level of inclusion content. Projection of size, type, distribution, and location of inclusions within the bar stock are desired identifiable characteristics of a material. Exogenous inclusions such as refractory material are the primary concern, but indigenous inclusions are also a concern. Reduction in both types of inclusions is desired. The Phase I effort will include prototype plans to be developed under Phase II.

**PHASE II:** Develop and demonstrate a prototype production process with creation of sample material. Determination of the size, type, distribution, and location of inclusions within the created material are the desired output. Comparison to current gear material X-53 double vacuum melt with ASTM E45 standard is required to verify improvement.

**PHASE III DUAL USE APPLICATIONS:** Finalize and demonstrate a larger scale production process with creation of a heat lot of steel material. Determine the size, type, distribution, and location of inclusions within the created material output. Comparison to current gear material X-53 double vacuum melt with ASTM E45 standard and fatigue test transverse created specimens to verify improvement.

## VERSION 5

Material failure due to inclusions limits the useful life of gear-and-bearing components. Commercial gear-and-bearing products would have higher and more predictable life. Aerospace, Industrial Machine, and other applications that require more predictable run time to avoid downtime and component changes would benefit from the technology.

### REFERENCES:

1. SAE Technical Standards Board. “AMS6308F: Steel, bars and forgings 0.90Si-1.0Cr-2.0Ni-3.2Mo-2.0Cu-0.10V (0.07-0.13C) vacuum arc or electroslag remelted.” SAE International, May 16, 2018. <https://www.sae.org/standards/content/ams6308f/>.
2. Sub-committee E04-09 on Inclusions. “ASTM E45 - 18a Standard Test Methods for Determining the Inclusion Content of Steel.” ASTM International. <http://www.astm.org/cgi-bin/resolver.cgi?E45>.
3. “ISO 4967:2013 Steel — Determination of content of non-metallic inclusions — Micrographic method using standard diagrams.” International Organization for Standardization, July 2013, <https://www.iso.org/standard/63156.html>.

KEYWORDS: Inclusion; refractory; steel; Exogenous inclusion; indigenous inclusion; X-53 (AMS 6308); double melt



# VERSION 5

N212-109

TITLE: Naval Aircrew Life Preserver Unit Automatic Inflation Device

RT&L FOCUS AREA(S): Autonomy

TECHNOLOGY AREA(S): Human Systems

OBJECTIVE: Optimally design and develop life preserver units (LPU) that automatically inflate for downed rotary-wing and non-ejection seat aircraft in which naval air crew have egressed their aircraft.

DESCRIPTION: The current LPU require either manual activation or oral inflation which require aircrew that are conscious and physically able to activate or orally inflate the LPU. Aircrew in non-ejection aircraft must manually activate their LPUs. In the event of partial or total non-inflation, aircrew must tread water while orally inflating their LPUs. A recent fatality occurred when an aircrew member was unable to manually or orally inflate the LPU and, subsequently, drowned. In other occurrences, injured or unconscious aircrew have been unable to manually or orally inflate their LPUs leading to loss of life.

This SBIR topic seeks a capability that would auto-activate LPU inflation. Innovative solutions must include consideration of whether aircrew are within the aircraft trying to egress or outside the aircraft and incapacitated. Critical escape and survival equipment should work on time, every time, with minimal/no user input (similar to ejection seat technology).

Major concerns related to early auto-inflation are creating a larger presented volume relative to egress paths, additional bulk to snag on the structure, vulnerability of the LPU to puncture or tear, or the occupant floating up and having to move downward against buoyancy to egress. Keeping the device stowed until needed is required for operational, evasion, and reserving LPU function for when actually required. Most of these concerns are serious to the point of being showstoppers, if they are realized. However, this topic presents the opportunity to preserve human life in situations where life could be lost, and that may result in an incremental improvement in survival for aircrew and other aircraft occupants. An automated system may be able to replace horse collar flotation devices for passengers who have not had egress training while wearing devices. While passengers are not the norm, this could also be important in increasing the odds of survival among passengers.

Under certain conditions, aircrew may desire not to have LPU automatic inflation or to disable it after water entry. For example, the aircraft might be in shallow water or partially submerged and the aircrew might want to remain inside. Or aircrew could be in a mission or survival situation where water entry is desired but LPU is not needed, e.g., shallow water crossing. Also in some situations—e.g., fixed wing ditch—aircrew can enter a raft without inflating the devices and save inflation for a more critical situation such as leaving the raft, for rescue, or capsize. As such, designs should include an optional disable capability.

The logic, data acquisition and flow, algorithm development, and the means to implement/package it with the LPU system will be key portions of the effort and will determine success. It is not required, but highly recommended that performers interact with the qualified naval LPU manufacturers as needed.

Additional considerations:

- (a) “escape buoyancy” should be addressed in the topic. Escape buoyancy is the total buoyancy from trapped air and insulation that is present in a survival suit “system” and still allow the wearer to escape a submerged helicopter. This includes net positive buoyant items that are part of the systems such as any foam mittens, hood, thermal liners and suit insulation, and trapped air.
- (b) does not appreciably increase the weight and bulk burden of the LPU;
- (c) operates in windy or calm air and in turbulent or calm water conditions;
- (d) operates at a submerged depth of less than or equal to 30 ft (9 m);

## VERSION 5

- (e) operates in cold water (32 °F (0 °C)) through the range of freshwater and seawater salinities;
- (f) operates in chlorinated swimming pool water;
- (g) operates reliably in cold and hot ambient air (-65 °F [-54 °C] to 160°F [71.1 °C]);
- (h) resists inadvertent actuation while traversing ship ladders/hatches, operating within 120 knot rotor outwash, conducting pre-flight inspections and boarding aircraft, flying routine missions, flying combat missions, and egressing aircraft in routine or emergency situations;
- (i) does not create hazards (e.g., injury, foreign object debris, snag/trip, static discharge) in any mission or survival operations to include survivable vertical crash loads (those less than or equal to 5Gs);
- (j) does not interfere with vest or vest gear, armor/armor release, seat harnesses, fall arrest tethers, helmets or head-mounted gear, communication cords and devices, clothing or other body-mounted gear;
- (k) does not impede water survival or land survival procedures to include raft boarding and hoisting;
- (l) does not contribute to wearer's burn injury hazard;
- (m) does not give away wearer's position in covert day or night operations;
- (n) is tolerant of naval aviation environments (e.g., salt spray, humidity, drop impact, exposure to petroleum/oil/lubricant contaminants; exposure to sun);
- (o) has an obvious visual indicator for correct rigging;
- (p) possibly a design consideration is when/how to fully inflate. The key word here is "fully". Crews are wearing net negative buoyant gear loads, and it is possible that a flotation system could be designed that inflates in stages (immediate inflation, then to neutral state to enable egress or reduce effort to tread water/drown proof, then 15 s later to full state to serve as a surfacing aid and for flotation).
- (q) inflation at depth considerations. Crews surfacing quickly and holding their breaths can cause air trapped in their lungs to expand. This may rupture lung tissue (i.e., pulmonary barotrauma), which can lead to gas bubbles being released into the arterial circulation (i.e., arterial gas embolism).

Note: NAVAIR will provide Phase I performers with the appropriate guidance required for human research protocols so that they have the information to use while preparing their Phase II Initial Proposal. Institutional Review Board (IRB) determination as well as processing, submission, and review of all paperwork required for human subject use can be a lengthy process. As such, no human research will be allowed until Phase II and work will not be authorized until approval has been obtained, typically as an option to be exercised during Phase II.

PHASE I: Develop, design, and demonstrate feasibility of new and innovative solutions that have the potential for auto-activation for downed aircrew that are egressing an aircraft or who are on the outside of the aircraft and incapacitated. An analysis of the auto-activation for the range of the downed aircrew scenarios, in which it is or is not appropriate, must be performed, and the risks associated with auto-activation for the range of those scenarios must be addressed. Those trades must be realized in the proposed solution. The risks to the wearer of fully inflating an LPU in a submerged aircraft must be addressed, mitigated, and reported on as a part of Phase I. The Phase I effort will include prototype plans to be developed under Phase II.

Note: Please refer to the statement included in the Description above regarding human research protocol for Phase II.

PHASE II: Develop and produce a prototype naval aircrew LPU inflation device. Perform laboratory and human validation testing to evaluate performance in mission-representative scenarios. Develop life-cycle costs and supportability estimates.

Note: Please refer to the statement included in the Description above regarding human research protocol for Phase II.

## VERSION 5

PHASE III DUAL USE APPLICATIONS: Finalize the prototype, validate, integrate and transition to naval platforms. Coordinate with naval platforms to test and qualify production representative units as needed.

Commercial air and sea safety, general aviation over water safety, and recreational boating industries could all benefit from this technology.

### REFERENCES:

1. Kovach, G. "Deadly Osprey crash spurred safety changes." The San Diego Tribune, June 30, 2015. [https://www.sandiegouniontribune.com/military/sdut-osprey-crash-at-sea-command-investigation-2015jun30-story.html#:~:text=1%2C%202014%20during%20a%20deadly,Marine%20Corps%20photo%2Freleased.\)&text=The%20V%2D22%20Osprey%20that,mode%2C%20Marine%20Corps%20investigators%20concluded.](https://www.sandiegouniontribune.com/military/sdut-osprey-crash-at-sea-command-investigation-2015jun30-story.html#:~:text=1%2C%202014%20during%20a%20deadly,Marine%20Corps%20photo%2Freleased.)&text=The%20V%2D22%20Osprey%20that,mode%2C%20Marine%20Corps%20investigators%20concluded.)
2. Quinn, R. "Beach Marine one of four killed in Iraq copter crash." The Virginian-Pilot, December 7, 2006. [https://www.pilotonline.com/military/article\\_57e53572-0cf4-5301-a6d0-2901302a4bb5.html](https://www.pilotonline.com/military/article_57e53572-0cf4-5301-a6d0-2901302a4bb5.html).
3. "Naval Safety Center Annual Report 2019. Naval Safety Center, p. 15. [https://navalsafetycenter.navy.mil/Portals/29/Documents/ANNUAL%20REPORT-Updated%20JUL15\\_compressed.pdf?ver=2020-07-16-143235-193](https://navalsafetycenter.navy.mil/Portals/29/Documents/ANNUAL%20REPORT-Updated%20JUL15_compressed.pdf?ver=2020-07-16-143235-193).

KEYWORDS: Aircrew; LPU; life preserver units; flotation; auto-inflation; water survival; egress

# VERSION 5

N212-110 TITLE: Machine Learning, Tactical Cross-Domain Solution, Cryptography Module

RT&L FOCUS AREA(S): Artificial Intelligence (AI)/Machine Learning (ML);Cybersecurity;Networked C3

TECHNOLOGY AREA(S): Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Design and develop a Tactical Cross Domain Solution (CDS) Cryptography Module for a Manned-Unmanned Teaming (MUM-T) that will achieve certification per the National Security Agency (NSA) Cross Domain Enterprise Service (CDES)/National Cross Domain Strategy Management Office (NCDSMO) and achieve Authority to Operate (ATO).

DESCRIPTION: Currently, MUM-Ts employ encryption/decryption on their communications links, usually through dedicated box-level components referred to as Encryption Control Units (ECUs). The use of ECUs in unmanned aerial vehicles (UAVs) must be certified by the NSA as “Type 1”. The 10 OCT 2018 Department of Defense CIO memo, “Suspension of New Point-to-Point Cross Domain Solutions and Changes to Existing Point-to-Point Cross Domain Solutions Implementations,” directed that development of new point-to-point CDS solutions be halted in favor of “enterprise” CDS solutions managed and monitored by the National Cross Domain Strategy and Management Office (NCDSMO). In addition, NSA released the Cross Domain Solution Design and Implementation Requirements: 2019 Raise the Bar Baseline Release (RTB). The RTB policy identifies four foundational concepts for a CDS, which are Redundant, Always Invoked, Independent Implementations, and Non-Bypassable (RAIN).

Using the nomenclature of the NCDSMO, this SBIR topic-requested system would classify as a Tactical-Class Transfer CDS (TCDS) with environmental constraints such as heat, humidity, and vibration, as well as a need to operate in an environment where communications capabilities may be interrupted. Usually these TCDS systems support a limited number of message formats. For this SBIR topic, the TCDS system should be designed to use a modular design capable of supporting a potentially large number of message formats, although any single instantiation would likely support a smaller set of message formats based on MUM-T mission requirements.

The proposed MUM-T CDS cryptography module may be either a multifunctional ECU, or a chassis ECU with multiple crypto functions on computer Printed Circuit Board (PCB) slices, or multiple smaller ECU modules with crypto functions in individual modules electronically connected together or being stand-alone ECUs. The CDS cryptography module must be capable of supporting multiple CDS channels at 100 Mb/s in less than or equal to 0.5 watts and within a threshold 1.5 cubic inches with an objective 0.5 cubic inches and a weight of threshold 0.7 ounces with an objective of less than 0.5 ounces, certified for Top Secret and Below (TSAB) Interoperability environments. The “Raise the Bar” compliant CDS cryptography module key factors in an envisioned NCDSMO certified solution would have minimally:

- (a) an intelligent domain security hierarchy control point as an intellectual property (IP) core that is capable of reading, parsing, and intelligently routing to associate security domains, messages, data, images, and/or video. The proposed intelligent domain security hierarchy control point would be

## VERSION 5

able to automate Object Identifier/Globally Unique Identifier (OID/GUID) data tagging that can be used for data analytics and distribution in the DCGS-N Inc. 2 Multi-Domain Federated Query (MDFQ) Architecture; manage and disseminate diverse types and formats of multi-domain messages, data, images, and/or video with different volumes, velocities, variability, and veracity characteristics; and handle changes in formats/fields of existing messages, data, images, and/or video types and feeds from multiple data sources.

- (b) a scalable, guard-agnostic, cross-domain discovery service to communicate between different security domains allowing individual messages, images, or data fields within them to be selectively passed, blocked or changed.
- (c) reprogrammable or configurable rulesets that allow adaptability in configuring each security domain to automate the “man in the middle” screening of message exchanges, thereby accelerating communications and reducing human error.
- (d) pluggable filters, which include functions to filter data based on user programmable rulesets.
- (e) machine learning (ML) algorithms to create data-driven content checkers for data leakage prevention (DLP), autonomous screening of message exchanges with no operator required, and also for an adaptive power management solution.
- (f) a protocol adapter that uses an agile performance-enhancing proxy (PEP) protocol to be enabled during a disadvantaged network condition.
- (g) an operator interface that allows role-based access and administration for configuration of each security domain through a separate management port.
- (h) Raise the Bar Compliant filters supporting multiple message formats including images, video, audio, Link 16/JREAP-C, USMTF, FDMP, FTP, and SMTP formats.
- (i) modular connectors for a cross-platform solution to enforce domain separation using separate high- and low-data ports.
- (j) zero packet loss in disadvantaged networks where communication performance suffers, or is disrupted, or is not feasible due to characteristics of the datalink or subnetwork on the path to transfer information.
- (k) a scalable guard-agnostic cross-domain discovery service using a service-oriented architecture (SOA) to autonomously screen message exchanges with no operator required.
- (l) machine-to-machine (M2M) algorithm to authenticate all outbound traffic using the high assurance Transport Layer Security (TLS) cryptologic and NSA Key Management Infrastructure (KMI) trusted certificates with no operator required.
- (m) anti-tamper protection with device zeroization built-in.
- (n) full audit logging of all system, security, and message events.
- (o) encrypted storage of rule sets and audit logs.
- (p) secure boot and trusted platform verification upon power up.
- (q) authenticated, role-based, device administration through management port.

The CDS cryptography module must be able to operate in the following environments:

- Operational Temperature: -40 °C to 70 °C
- Storage Temperature: -51 °C to 85 °C
- Operational Altitude: 0–65,000 ft above sea level
- Mechanical Shock: 40g, 11 ms, each axis
- Vibration: Tracked and Wheeled Vehicle, Fixed-and Rotary-Wing Aircraft, Gunfire
- Fluid Contaminations: Diesel, Hydraulic, Oil, Bleach
- Relative Humidity: 10-95%
- EMI/EMC: MIL-STD-461F, RE102, CE102, CS101, CS114, CS115, CS116, RS103
- Power: MIL-STD-1275E, MIL-STD-704F

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program

## VERSION 5

Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances. This will allow contractor personnel to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Design and demonstrate feasibility of a flyable routing solution scalable to various platform configurations with a CDS addressing multiple security levels. Develop a draft architecture and plan for attaining NSA approval for cryptologic systems. The Phase I effort will include prototype plans to be developed under Phase II.

The Phase I final report must include in the appendices: (a) a plan for NCDSMO certification of the final design which would achieve Common Criteria Evaluation Assurance Level (EAL) greater than four; (b) a Hardware/Software/Firmware Requirements/Design Specifications including use case diagrams (i.e., file drop, API/socket data transfers, database data transfers, video transfers, multiple CDS/file decomposition); and (c) a Design Description containing a full and detailed description of the proposed MUM-T CDS cryptography module design, including detailed system design, a traceability matrix to the software requirements and interfaces which abstracts isolation and security low-level communication details and exchanges.

PHASE II: Further design and develop the solution identified in Phase I into a prototype. In conjunction with the Government, develop simulated data and then use that data to demonstrate the prototype. Develop an unclassified set of controls to handle organic and off-board classified data types provided by the Government. Demonstrate features and function that would be best suited for transition into an operational environment.

Initiate process of attaining NSA approval for designed hardware and software.

Finalize the design, fabricate the design, and test the design developed in Phase I for proof of operation and ability to be certified. Finalize the steps necessary for NCDSMO certification and ATO.

Deliver prototype hardware and software documentation, which should include reports on: NSA Certification; Decryption; Encryption; Authentication; Transmission Security; Algorithms; Cryptographic Status; Cryptographic Alerts; Key Management Infrastructure -Enabled; Re-programmability; Protocols; Interfaces; Over-the-Network-Keying; Over-the-Air-Re-key; Key Storage; Multiple User Access; Key Manager; Crypto Manager, and System Manager.

Work in Phase II may become classified. Please see note in the Description section.

PHASE III DUAL USE APPLICATIONS: Complete development of the cross-domain control measures and perform final testing in a Government-designated simulation environment. After identifying specific data types and classifications of airborne system data, demonstrate a fully capable multilevel security CDS in a live fly event. Continue work with the Government sponsor to gain NSA approval for provided approach and transition to applications across naval airborne platforms.

The control measures and techniques employed may benefit companies seeking to protect proprietary data while working with other organizations. This technology will apply beyond the contractors supporting the DoD. Medical, financial, and civilian electronics industries will benefit from a technology that allows



## VERSION 5

networking with competitors for collaboration while preventing proprietary or personal data from spillage onto an improper domain.

### REFERENCES:

1. Schneier, B. "Applied cryptography 2nd." John Wiley and Sons, Inc. New York, 1996. <https://doi.org/10.1002/9781119183471>.
2. Ahmed, Z., Rahmatullah, M. M. and Jamal, H. "Security processor for bulk encryption." Proceedings of the 16th International Conference on Microelectronics (ICM), December 2004, pp. 446-449. <https://doi.org/10.1109/ICM.2004.1434610>.
3. Luo, X., Chan, E. W. and Chang, R. K. "CLACK: A network covert channel based on partial acknowledgment encoding." 2009 IEEE International Conference on Communications, June 2009, pp. 1-5. <https://doi.org/10.1109/ICC.2009.5198826>.
4. Luo, X., Chan, E. W., Zhou, P., & Chang, R. K. (2012). Robust network covert communications based on TCP and enumerative combinatorics. IEEE Transactions on Dependable and Secure Computing, 9(6), 890-902. <https://doi.org/10.1109/TDSC.2012.64>.
5. Diffie, W. and Hellman, M. "New directions in cryptography." IEEE transactions on Information Theory, 22(6), 1976, pp. 644-654. <https://doi.org/10.1109/TIT.1976.1055638>.
6. "Information Assurance Capabilities, Data at Rest Capability Package, Version 4.0." National Security Agency/ Central Security Service, January 2018. <https://www.nsa.gov/Portals/70/documents/resources/everyone/csfc/capability-packages/dar-cp.pdf>.
7. "Information Assurance Capabilities, Commercial Solutions for Classified, Harnessing the Power of Commercial Industry." National Security Agency/ Central Security Service, September 2018. <https://www.nsa.gov/Portals/70/documents/resources/everyone/csfc/csfc-faqs.pdf>.
8. MIL-STD-810H, DEPARTMENT OF DEFENSE TEST METHOD STANDARD: ENVIRONMENTAL ENGINEERING CONSIDERATIONS AND LABORATORY TESTS (31-JAN-2019)." [http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H\\_55998/](http://everyspec.com/MIL-STD/MIL-STD-0800-0899/MIL-STD-810H_55998/).
9. "Cross Domain Solution (CDS) Design and Implementation Requirements 2019 Raise the Bar (RTB) Baseline Release Draft Version 2.0 rev12." Doc ID: NCDSMO-R-00008-002\_00, National Security Agency/ National Cross Domain Strategy and Management Office, 2 October 2019

KEYWORDS: Multilevel Security; Cross Domain Solution; CDS; Data Sorting; Adaptive; Small Form-factor; Machine Learning



# VERSION 5

N212-111      TITLE: Technology for Transmitting and Receiving Airborne, High-Speed, Wideband, Covert Communications

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR); Networked C3

TECHNOLOGY AREA(S): Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a low-cost, covert, high-speed, high-density means of transmitting and receiving broadband data for use on Navy Land/Sea/Air platforms.

DESCRIPTION: The U.S. Navy requires a high-capacity, covert communication link providing two-way communication through free space. This communication link must be covert, or undetectable, which has a low probability of intercept (LPI) or a low probability of detection (LPD) and cannot be susceptible to jamming. The communication path must allow for fast, large-data transfer(s) from one aircraft to another aircraft and/or sea- or land-based hub. The types of data include, but are not limited to, the following types of data: maritime tactical information, imagery (Still and Full Motion Video), Synthetic Aperture Radar, Multi- and hyper-spectral imagers, Precise Navigation and Timing (PNT) data, Electronic Warfare, and Acoustic data.

The goal of this SBIR topic is to develop a covert, wideband communication device that supports a 100 Mbps data transfer rate at line of sight ranges (150 nm). The first challenge for many engineers in wireless communication design is how to overcome white Gaussian noise. The proliferation of wireless technologies has also added hostile noises as a major cause of interference. A covert, high-bandwidth communication device could overcome a harsh Gaussian environment even with the addition of hostile noises while maintaining a high-bandwidth data transfer. If Radio Frequency (RF) is used as the transmission source, desired bands are L band to X band, Ku band, and Ka band ability with the ability to transmit and receive (TR/RX) in multiple bands. The volume of the device should be less than 4.5 ft<sup>3</sup> (0.127 m<sup>3</sup>). The weight should be less than 50 pounds (22.7 kg). The estimated cost per unit should be less than \$50K per kit. Conformal antennas are desired to limit the drag impacts on the host aircraft. The system is required to be undetectable outside of the main beam (i.e., highly directional, meaning you have to be in the path to intercept). For RF, the system should be able to null noise sources, in addition to being a non-detectable signal below the RF noise floor and agile enough to mitigate against jamming sources. The desire is to limit the number of moving parts to reduce the sustainment footprint of this device.

PHASE I: Develop, design, and demonstrate a strategy, taking into consideration the feasibility and suitability for a covert high-speed, high-capacity airborne communication link. Identify potential roadblocks likely to be encountered and possible roadblock solutions. Recommend an architecture and implementation plan. Illustrate the benefits of being able to pass high-speed, high-capacity data covertly. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Based on the architecture and algorithms, develop a working prototype to include high-level requirements, software development, testing, and demonstration.

# VERSION 5

PHASE III DUAL USE APPLICATIONS: Perform final testing, and finalize the prototype. Develop platform integration execution plans, and engineering documentation, suitable for the transition of a functional prototype.

Covert netted high-bandwidth communications, wireless sensors and multimedia communications are increasingly becoming a required asset for success in modern society. As a result, issues surrounding their effective use, safety, and security are becoming more important. Even for commercial applications, covert commercial communication platforms will help protect private and sensitive information by reducing the possibility of interception and compromise.

Additionally, wireless communications often suffer from hostile noises or hostile noise environments. This would have commercial use for anyone who uses wireless technologies.

## REFERENCES:

1. National Research Council, Division on Engineering and Physical Sciences Naval Studies Board, Committee on C4ISR for Future Naval Strike Groups. "C4ISR for future naval strike groups." National Academies Press, 2006. <https://play.google.com/store/books/details?id=9w5HPwE0A6sC&gl=us>.
2. Perkins, W. and Pizzimenti, N. "Alliance airborne anti-submarine warfare." NATO Joint Air Power Competence Centre, June 2016. <https://www.japcc.org/portfolio/alliance-airborne-anti-submarine-warfare/>.
3. "DoD 5220.22-M National Industrial Security Program Operating Manual (Incorporating Change 2, May 18, 2016)." Department of Defense, February 28, 2006. <https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodm/522022m.pdf>.

KEYWORDS: Covert; network; high-capacity; RF; optical; survivable; communications

## VERSION 5

N212-112      TITLE: Extending the Surveillance Horizon for Improved Ship Self-Defense Against Hypersonic Cruise Missiles

RT&L FOCUS AREA(S): Hypersonics

TECHNOLOGY AREA(S): Air Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop and demonstrate critical elements of advanced airborne radar system designs for the detection and tracking of supersonic and hypersonic cruise missiles to provide early cueing of ship self-defense systems.

**DESCRIPTION:** Navy ships face a variety of missile threats. Highly advanced and very capable ship self-defense systems are in place to defeat these threats. However, hypersonic cruise missile threats operating at lower altitudes pose a unique challenge. As opposed to ballistic missile trajectories where Navy guided missile destroyers and cruisers have on the order of several minutes to detect, track, lock onto, and then launch interceptors against a hypersonic reentry vehicle, low flying missiles [Refs 1–3] provide as little as 10 seconds (s) of flight time above the ship's radar horizon before missile impact. Some supersonic missile threats present similar challenges. An airborne platform, either manned or unmanned, with a suitable radar system operating in the vicinity of the ship could—in principle—dramatically extend the engagement timeline by providing early detection, tracking, and cueing to the ship. The most obvious candidate aircraft to host the radar system would be on high altitude long-endurance (HALE) and medium-altitude long-endurance (MALE) unmanned aircraft (UA). Hosting this desired capability on existing Navy airborne radar systems is very desirable and worthy of consideration. Even when a threat vector is identified so as to constrain the radar surveillance volume, the detection and tracking timeline for single or multiple inbound missiles whose radar return may be buried within a plasma envelope is extremely challenging. The desired solution is a radar mode and signal processing approach capable of being hosted in modern Navy airborne radar systems.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances. This will allow contractor personnel to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

**PHASE I:** Develop, design, and demonstrate feasibility of a high-fidelity target-and-clutter model to establish radar system mode and signal processing requirements when operating from a HALE or MALE UA platform utilizing open-source literature on potential-threat, anti-ship, hypersonic cruise missile

## VERSION 5

systems, their flight profiles, and expected radar cross sections, including the potential plasma surrounding a hypersonic missile. With those requirements, develop conceptual radar system mode implementation concepts and evaluate those using the missile and radar models. Identify the most promising approaches from a detection and tracking performance perspective. Prepare a Phase II plan that demonstrates operational and technical feasibility of the proposed approach. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Refine the radar architecture using threat-and-host platform information provided by the Navy. Increase model fidelity, as required, to more confidently characterize the radar's performance in an operational environment. Refine the radar system performance requirements as necessary based on modeling results. Demonstrate and document results of tests of critical technologies identified in Phase I. At the end of Phase II, a prototype radar system design should be completed and delivered to the Navy. The design should be sufficiently detailed to inform the scope of a Phase III development program.

Work produced in Phase II may become classified. See Description for details.

PHASE III DUAL USE APPLICATIONS: Complete development, perform final testing, and integrate and transition the final solution to naval airborne radar systems either through the radar system OEM or through third party radar mode developers.

The algorithmic approaches could be utilized by a very wide variety of airborne, surface, and space-based radar systems for the detection and tracking of very high-speed objects including those that are moving in a high-clutter environment.

### REFERENCES:

1. Howard, A. "Fast and furiously accurate: Conventional hypersonic weapons need precision to match their speed.." U.S. Naval Institute Proceedings, 145(7), July 2019, p. 1397. <https://www.usni.org/magazines/proceedings/2019/july/fast-and-furiously-accurate>.
2. Osborn, K. "Could the U.S. military use lasers to kill Russia or China's hypersonic missiles?" The National Interest, August 27, 2019. <https://nationalinterest.org/blog/buzz/could-us-military-use-lasers-kill-russia-or-chinas-hypersonic-missiles-76416>.
3. Mizokami, K. "Russia's new warships will pack hypersonic missiles." Popular Mechanics, December 12, 2019. <https://www.popularmechanics.com/military/weapons/a30200046/russian-warships-hypersonic-missiles/>.

KEYWORDS: Radar; Hypersonic; Cruise Missile; Ship Self Defense; Detection in Clutter; Anti-Ship Missiles

# VERSION 5

N212-113      TITLE: Modeling of Solid-State Materials Consolidation Repair Process for Static Strength and Fatigue Life Predictions

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platforms; Materials / Processes

OBJECTIVE: Develop a thermal/mechanical/metallurgical-analytical tool to predict static strength and fatigue life of solid-state materials consolidation process for structural repairs via process modeling.

DESCRIPTION: This effort will further the Navy's push to take advantage of solid-state additive methods for repair/sustainment and reduce reliance on experiments alone by improving our understanding of the physics involved, assisting in selecting appropriate materials, and improving process parameter optimization. Various solid-state materials consolidation processes have proven to be attractive and promising procedures to perform repair of metallic structural aircraft components. An attractive aspect is the ability to add material with a reduced heat input, thermal gradients, and residual stresses compared to melting-based technologies. The plastic flow-induced diffusion process can introduce a stronger bonding at material interfaces, allowing for bonding of dissimilar materials that other methods cannot accomplish [Refs 1, 4]. The various solid-state repair methods involve a large range of interdependent relationships between the microstructure, thermal, and mechanical aspects. Examples of important phenomena include plastic deformation, dynamic recrystallization, and heating-and-cooling rates [Ref 3]. While no melting is involved, the various solid-state processes induce heating, which affects the repair material and substrate and needs to be considered. Minimizing the impact to the substrate material is critical to doing no harm during the repair process.

Given the coupled physical mechanisms, the large number of geometry and process dependent variables to control, and the material evolution associated with solid-state materials consolidation repair, it is imperative to develop a physics-based modeling tool. Such a tool will reduce both testing costs and time to identify important process parameters. The process parameters need to meet the performance requirements in terms of restoring or enhancing the strength and fatigue life of the damaged components. That is, any repair should meet a part's static strength requirements and provide increased fatigue life compared to no repair.

The developed tools should provide conservative estimates of the static strength and fatigue life. In addition, prediction of damage initiation and propagation in repaired components is important, but still in its formative stage due to the complexity associated with material heterogeneity, defects, and residual stress field. To achieve these goals, the tool will need to consider thermal, mechanical, and metallurgical phenomena. The tool should also predict bond strength, damage initiation, and its progression in a repaired component. In order to predict strength and durability, the impact of the thermal history and the plastic strain of the process on the repair and substrate material's microstructure will require consideration [Refs 1, 3]. The focus material should be aerospace-grade aluminum alloy (e.g., 2024 or a 7000 series aluminum alloy). This modeling tool will advance the Navy's ability to analyze solid-state repairs, setting the stage for improved repair options.

PHASE I: Develop an integrated computational modeling framework for a solid-state materials consolidation repair method. Such a framework should simultaneously consider thermal, mechanical, and metallurgical phenomena. The simulation should consider process simulation and structural analysis. Ensure that the concept methodology in Phase I demonstrates its ability to model the process's thermal history and residual stresses. At a minimum, provide the methodology for the consideration of bond strength, damage initiation, and its progression of solid-state repaired components under static and fatigue loading in Phase II. The Phase I effort will include prototype plans to be developed under Phase II.

## VERSION 5

PHASE II: Fully develop, verify, and validate a prototype modeling simulation tool for solid-state materials consolidation repair subject to static and fatigue loading. Demonstrate its ability to optimize repair on aircraft components for improved static strength and fatigue life.

PHASE III DUAL USE APPLICATIONS: Finalize the prototype. Perform final testing to demonstrate the analysis model's ability to provide conservative, but structurally useful, static strength and fatigue life for a variety of repairs (e.g., hole damage and corrosion) and materials. Transition the tool.

Commercial aviation has similar incentive to repair damaged aircraft and get them airworthy quickly. This analysis capability will be just as useful for the commercial aviation industry.

### REFERENCES:

1. Hang, Z. Y., Jones, M. E., Brady, G. W., Griffiths, R. J., Garcia, D., Rauch, H. A., Cox, C. D. and Hardwick, N. "Non-beam-based metal additive manufacturing enabled by additive friction stir deposition." Scripta Materialia, 153, 2018, pp. 122-130. <https://doi.org/10.1016/j.scriptamat.2018.03.025>.
2. Cai, W., Daehn, G., Vivek, A., Li, J., Khan, H., Mishra, R. S. and Komarasamy, M. "A state-of-the-art review on solid-state metal joining." Journal of Manufacturing Science and Engineering, 141(3), 2019. <https://doi.org/10.1115/1.4041182>.
3. Griffiths, R. J., Petersen, D. T., Garcia, D. and Yu, H. Z. "Additive friction stir-enabled solid-state additive manufacturing for the repair of 7075 aluminum alloy. Applied Sciences, 9(17), 2019, p. 3486. <https://doi.org/10.3390/app9173486>.
4. Cavaliere, P. and Silvello, A. "Crack repair in aerospace aluminum alloy panels by cold spray." Journal of Thermal Spray Technology, 26(4), 2017, pp. 661-670. <https://doi.org/10.1007/s11666-017-0534-9>.

KEYWORDS: Solid-state material consolidation; additive repair; Static strength; Fatigue life prediction; additive friction stir deposition; cold spray



# VERSION 5

N212-114      TITLE: Advanced Low Probability of Intercept/Low Probability of Detection Radar (LPI/LPD) Techniques Using Artificial Intelligence Driven Methods

RT&L FOCUS AREA(S): Artificial Intelligence (AI)/Machine Learning (ML);General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Air Platforms;Electronics

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Design and develop advanced low probability of intercept/low probability of detection (LPI/LPD) radar techniques using artificial intelligence (AI) driven methods.

DESCRIPTION: The use of low probability of intercept/low probability of detection (LPI/LPD) radar techniques in radar and communication systems operating in adversarial environments has been common for many years. A wide range of techniques have been utilized in various combinations, including wide operational bandwidth, frequency agility, proper power management, antenna side lobe reduction, and advanced scan patterns, as well as host LPI waveform designs including binary phase codes, polyphase codes, Barker codes, Frank codes, and Polytime codes. Countermeasures to these techniques have been widely documented in open source literature. Many of the more recent approaches rely on machine- and deep learning-based detection and localization algorithms to dramatically reduce the effectiveness of conventional LPI/LPD radar techniques. The Navy requires the development of highly adaptive, advanced AI-based LPI/LPD radar techniques to regain and maintain an enduring advantage in the presence of capable adversaries. Computational resources to host this capability vary significantly across the candidate transition platforms. As a result, the computational efficiency of the approach along with its robustness and training requirements should be considered important criteria in the selection of an AI technique.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances. This will allow contractor personnel to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Develop concepts for multiple synergistic LPI/LPD radar techniques that are able to quickly adapt in response to the tactical environment. One or more AI-based decisions engines to achieve this adaptability. The concepts should directly address how the approach will counter those advanced machine and deep learning LPI/LPD radar techniques widely discussed in open source literature. Consideration should be given to how invasive each conceptual approach is in terms of hardware requirements and performance impacts. The Phase I effort will include prototype plans to be developed under Phase II.



## VERSION 5

PHASE II: Based on Phase I results, candidate concept(s) will be matured through more detailed high-fidelity analyses with a focus on a particular legacy radar system. Examine sensor integration concepts. Working with the Navy sponsor, assess hardware, software, and firmware impacts to accommodate the candidate techniques. Identify critical technical challenges and perform necessary analysis and as required experimentation to understand the associated risk. The Phase II deliverable should provide a detailed conceptual approach with supporting analyses of sufficient detail to support follow-on design and integration in the candidate radar system.

Work in Phase II may become classified. Please see note in Description section.

PHASE III DUAL USE APPLICATIONS: Complete development, perform final testing, integrate, and transition the final solution to naval airborne radar systems.

The techniques could be utilized by commercial applications in commercial communication and data systems.

### REFERENCES:

1. Kong, S. H., Kim, M., Hoang, L. M. and Kim, E. "Automatic LPI radar waveform recognition using CNN." IEEE Access, 6, 2018, pp. 4207-4219. <https://doi.org/10.1109/ACCESS.2017.2788942>.
2. Kookamari, F. H., Norouzi, Y. and Nayeibi, M. M. "Using a moving aerial platform to detect and localise a low probability of intercept radar." IET Radar, Sonar & Navigation, 11(7), 2017, pp. 1062-1069. <https://digital-library.theiet.org/content/journals/10.1049/iet-rsn.2016.0295>.
3. Alrubeaan, T., Albagami, K., Ragheb, A., Aldosari, S., Altamimi, M. and Alshebeili, S. "An Investigation of LPI Radar Waveforms Classification in RoF Channels." IEEE Access, 7, 2019, pp. 124844-124853. <https://doi.org/10.1109/ACCESS.2019.2938317>.

KEYWORDS: Radar; Low Probability of Intercept; LPI; Low Probability of Detection; LPD; Counter Electronic Attack; Maritime Surveillance; Waveform Design

# VERSION 5

N212-115 TITLE: Additive Fiber Reinforced Composite Repair for Aircraft

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes

OBJECTIVE: Develop a novel additive material deposition system that produces high-quality composite laminate repairs that return parts to original strength.

DESCRIPTION: High-performance composite materials used on current, and future, aircraft construction will exhibit damage and wear throughout their lifetimes. Repair methods usually consist of damaged material removal, surface preparation, and applying a repair patch in order to bring the structure back up to original strength. Although repair systems exist, these can be very labor intensive. Much effort is spent on cutting and handling the repair materials. This handling often produces excess waste as the maintainer must cut circular material to make the patches from stock material that comes in square sheets. These repairs must be carefully cut to fit the damaged area they are replacing, often made from successive circular layers in a step scarf geometry. There is also the struggle with time as the liquid resin systems either pre-impregnated in the fiber or applied from a two-part mixture have a finite shelf life. Finally, there is a great amount of training associated with individuals doing repair to produce consistent and quality products every time.

Recent advances in Additive Manufacturing (AM) have the potential to make automated repairs a reality. Stemming from earlier work on Automated Fiber Placement (AFP), commonly used in industry, AM has moved from printing thermoplastics to fiber-reinforced thermoplastics and thermosets [Ref 1]. It has been shown that the resulting parts are not only stronger, but contain nearly as much fiber content as the high-performance composites used in making aircraft. There have also been advances in resin materials. Recent products featuring higher temperature thermoplastics are becoming commercially available. Thermosetting resins such as epoxies are being developed [Ref 2]. These resins can meet the structural and environmental properties demanded by naval aircraft. Coupling the superior strength of fiber reinforcement with durable, high temperature-resistant resins are the next technological step for performance AM [Ref 3].

An automated repair system will leverage the miniaturization of composite processing through AM to enable fleet maintainers to make faster more consistent repairs to composite aircraft. The user would mount the system over the damaged area and load in the repair materials. Repair patch outer dimensions may reach a maximum size of up to 18 inches and a minimum size of 5 inches. Applying repair material at the point of deposition will eliminate the waste generated by hand cutting pre-impregnated or wet layup composites. It will also speed up repair as the maintainer would not have to handle and mix resin before wetting out the dry fibers before cutting to size. Consistency will also improve as the resin is pre-mixed and uniformly impregnated into the fiber feedstock for the system. Using the aircraft as a tool surface, the proposed system can apply local pressure and heat to improve consolidation of the fibers, as well as, cure. Machine vision can be used to confirm ply orientation, scan for Foreign Objects and Debris (FOD), and provide documentation of the process which is useful for Digital Twin applications. Once complete, the user can remove the system and the leftover repair materials to be stored for future repairs.

The objective is to be able to install, operate, and cure the repair in one shift (8 hr) although longer duration is acceptable depending on technology maturity. Develop and add the capabilities of machine vision to confirm repair ply size, orientation, and if FOD/defects exist. Further refine the intended repair material to be deposited by this system. Utilize a resin system with a cure temperature no greater than 350 °F (177 °C) although lower is desired. Show that the resin is fully cured when the intended system and repair process is complete. Perform additional mechanical testing per ASTM Standard of the repair material to confirm that physical and mechanical properties are suitable for a repair system.

# VERSION 5

Desired threshold mechanical performance are listed below.

## Threshold Composite (0°/90°) Symmetric Laminate Mechanical Properties

- Short Beam Shear Average Strength: 9 ksi Room Temp Ambient, 6 ksi 180 °F (82 °C) wet
- Tension Average Strength: 115 ksi Room Temperature Ambient, 109 ksi 180 °F (82 °C) wet
- Tension Average Modulus: 10.36 msi Room Temperature Ambient, 9.74 msi 180 °F (82 °C) wet
- Compression Average Strength: 69 ksi Room Temperature Ambient, 48 ksi 180 °F (82 °C) wet
- Compression Average Modulus: 7.91 msi Room Temperature Ambient, 7.62 msi 180 °F (82 °C) wet.

The final repair material will have to undergo sufficient mechanical testing and characterization such that strength allowables can be generated and used to perform repair analysis. The proposer should conduct demonstrations of the material being deposited and utilize cross-sectional imaging and Non-Destructive Inspection (NDI) to confirm porosity does not exceed 4% by volume. The proposer should perform acid digestion of repair material to confirm a fiber content.

The goal is to meet or exceed 50% fiber content by volume. The final system should be such that it can be handled, carried, and placed by no more than two personnel.

PHASE I: Develop, design, and demonstrate the feasibility of a portable system that can additively repair a composite material through the automated deposition of thermoset polymer and carbon fiber reinforcement. **Identify and prototype a fiber and resin system that will be used by this machine.** Fiber may be continuous or discontinuous. The final intended resin system should have a wet Glass Transition temperature (T<sub>g</sub>) of no less than 230 °F (110 °C). Demonstrate the system by depositing and consolidating material with a quasi-isotropic fiber orientation on a flat surface. Also, demonstrate that the system is capable of applying subsequent layers in such a manner that the net shape is the stepped scarf normally used in composite scarf repairs. Provide cross-sectional imaging, and additional analysis of these materials to inspect for porosity and fiber content. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Develop and demonstrate the technology to show that it can deposit material on curved surfaces. Demonstrate that it can deposit material in the scarfed recess left over from removing damaged material from a parent laminate. Integrate and refine the developed system such that it can be handled, carried, and placed by no more than two personnel. Refine the prototype system such that it can be securely mounted in reference to an aircraft's outer surface. Provide refined demo system as a deliverable to be used by NAVAIR.

PHASE III DUAL USE APPLICATIONS: Perform additional work to produce allowables data sufficient for traditional repair analysis per aircraft platform. Determine an adhesive system to be used for this repair. Ideally this would be one currently used in the fleet although the repair's own resin matrix may be sufficient. Prove this with mechanical testing. Complete full integration of the technology from a prototype to a commercially viable system. Provide this system as well as a comprehensive manual for its operation. Integrate the machine vision system into current aircraft maintenance tracking procedures.

Aircraft repair is common in the aerospace industry including transportation as well as military use. Composites are becoming more and more commonplace for commercial aircraft with the skin and stringers taking up much of the loads as seen with the Boeing 787. Being able to restore material properties to their original strength in an automated and consistent manner will keep aircraft flying longer, reducing costs for air carriers. Additional use can be found within the Army and Air Force for their composite aircraft.

# VERSION 5

## REFERENCES:

1. Brenken, B., Barocio, E., Favaloro, A., Kunc, V. and Pipes, R. B. "Fused filament fabrication of fiber-reinforced polymers: A review." Additive Manufacturing, 21, 2018, pp. 1-16. <https://doi.org/10.1016/j.addma.2018.01.002>.
2. Nawafleh, N. and Celik, E. "Additive manufacturing of short fiber reinforced thermoset composites with unprecedented mechanical performance." Additive Manufacturing, 33, 2020, 101109. <https://doi.org/10.1016/j.addma.2020.101109>.
3. Kim, H. J., Kim, H. S., Lee, G. Y., Kim, M. S., Min, S. H., Keller, R., Ihn, J. B. and Ahn, S. H. "Three-dimensional carbon fiber composite printer for CFRP repair." Composites Part B: Engineering, 174, 2019, 106945. <https://doi.org/10.1016/j.compositesb.2019.106945>.

KEYWORDS: Repair; Composites; Additive Manufacturing; Automated Fiber Placement; Machine Vision; Portable

# VERSION 5

N212-116 TITLE: Acoustic Tomography Using Tactical Sensors

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Battlespace Environments

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Inform Air Anti-Submarine Warfare (ASW) operations by applying acoustic tomography through leveraging the tactical sonobuoy sensors used for wide-area search to estimate the three-dimensional sound-speed field.

**DESCRIPTION:** Air ASW systems rely on environmental information to plan sensor fields and assess the performance of the mission afterwards. In future Air ASW systems designs, environmental predictions will be used to better separate targets from clutter. Sound speed is a fundamental component of this suite of environmental information and is critical for determining transmission loss. Transmission loss is an important parameter in reconciling the sonar equation and is needed to understand achieved search performance and to derive performance estimates. Maximum acceptable Transmission Loss is highly dependent on environmental factors such as ambient noise and reverberation.

Currently, Maritime Patrol Reconnaissance Aircraft rely on a combination of pre-flight estimates of the sound-speed field, augmented with sparse direct measurements of the sound speed using air expendable bathythermograph (AXBT) sonobuoys. An AXBT provides the sound-speed profile only for the point at which it enters the water, however; distributed fields of sonobuoys can extend over large areas and more complete estimates of the sound-speed across the sonobuoy field are needed in order to provide improved mission planning and execution. Dropping more AXBT sensors is not desired because of payload constraints on the aircraft, lost search time deploying more sensors for environmental assessment, and increased cost for each mission from dropping more buoys.

Acoustic tomography has been previously applied to improve ASW situational awareness [Ref 1-3]. This SBIR topic will take advantage of the information already used by Air ASW systems to infer the sound-speed field by using acoustic tomography drawn from bistatic active sonar measurements used in wide-area search. Acoustic tomography [Ref 4] measures acoustic travel times between two points, along a multitude of paths, crossing at many different angles, to reconstruct the sound speed in a manner similar to medical computer aided tomography (CAT) scans. One constraint associated with using data from air deployed sensors is the limited bandwidth of both the source and receiver (on the order of 100 Hz). It may also be the case that not all receivers in the field reliably receive the source transmission. Any derived sound speed should be less than 1% different from a measured value at the same depth when a measured value is available for comparison.

Modern multistatic sonobuoy fields offer a similar multitude of paths, and aircraft avionics can readily measure travel times as part of the sonar processing chain. In recent years, the size of the sonobuoy fields have grown, and the accuracy of buoy location estimates during a mission has increased. These two trends appear to make acoustic tomography using tactical sensors more feasible than in the past.

## VERSION 5

Air ASW systems that benefit from this technology include: mission planning, tactical decision aides, post-mission assessment systems at tactical support centers, and onboard target detection processing systems.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances. This will allow contractor personnel to perform on advanced phases of this project as set forth by DCSA and NAVAIR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Conduct a study to account for the impact of various factors (e.g., buoy location uncertainty (0 – 1 NMI uncertainty), time of arrival uncertainty (+/- 1 sec or less), and sonobuoy spacing (5 km – 15 km), demonstrating the feasibility of the proposed approach through the use of simulations. Demonstrate using simulations that transmission loss estimates for tactical sensors, based on climatology and now-casts (Generalized Digital Environmental Model (GDEM) or Hybrid Coordinate Ocean Model (HYCOM)), can be improved by using acoustic tomography methods via tactical sensors. Demonstrate through simulations that Transmission Loss prediction accuracy using acoustic tomography for the entire multistatic sonobuoy field is within +/-6 dB of TL estimates generated by using GDEM or HYCOM at the point where that data is available. The Phase I effort will include prototype plans and software architecture to be developed under Phase II.

PHASE II: Develop a prototype processing algorithm suitable for integration into mission planning tools and onboard target discrimination algorithms. Analyze real-world data to show improved reconciliation of measured target detections and measured echo levels with environmental predictions of echo levels and signal excess that incorporate tomography results.

Work in Phase II may become classified. Please see note in Description paragraph.

PHASE III DUAL USE APPLICATIONS: Finalize and implement the capability as part of an operational sonar system. Transition of this capability should utilize the Advanced Product Builds (APB) process.

The tomography techniques developed under this effort have application across the Navy for sonar, radar, electro-optic, and other sensor devices. Other commercial applications for this technology are oil exploration and predicting storm tracks based on sea temperature.

### REFERENCES:

1. Cornuelle, B., Munk, W. and Worcester, P. "Ocean acoustic tomography from ships." Journal of Geophysical Research: Oceans, 94(C5), May 15, 1989, pp. 6232-6250. <https://doi.org/10.1029/JC094iC05p06232>.
2. The Acoustic Mid-Ocean Dynamics Experiment Group. "Moving Ship Tomography in the North Atlantic.", EOS Science News, American Geophysical Union, 75(2), January 11, 1994, pp. 17-23. <https://doi.org/10.1029/94EO00509>.
3. Munk, W., Worcester, P. and Wunsch, C. "Ocean acoustic tomography." Cambridge University Press, 2009. [https://books.google.com/books?hl=en&lr=&id=wLcTlu\\_uHIwC&oi=fnd&pg=PP1&dq=Ocean+Acoustic+Tomography&ots=pEfwhIRktR&sig=WiCI8or\\_IF\\_LN6LDThJJdFdXw6M#v=onepage&q=Ocean%20Acoustic%20Tomography&f=false](https://books.google.com/books?hl=en&lr=&id=wLcTlu_uHIwC&oi=fnd&pg=PP1&dq=Ocean+Acoustic+Tomography&ots=pEfwhIRktR&sig=WiCI8or_IF_LN6LDThJJdFdXw6M#v=onepage&q=Ocean%20Acoustic%20Tomography&f=false).

## VERSION 5

4. Delbalzo, D. and Klicka, J. "Uncertainty-based adaptive AXBT sampling with SPOTS." [Paper presentation]. OCEANS '09, MTS/IEEE, Biloxi, MS, United States, October 26-29, 2009. <https://doi.org/10.23919/OCEANS.2009.5422074>.
5. "DoD 5220.22-M National Industrial Security Program Operating Manual (Incorporating Change 2, May 18, 2016)." Department of Defense, February 28, 2006. <https://www.esd.whs.mil/portals/54/documents/dd/issuances/dodm/522022m.pdf>.

KEYWORDS: Acoustic Tomography; Sound Speed Profile; Multistatics Mission Planning; Target Detection; Target Search; Intelligent Search; sonobuoy



# VERSION 5

N212-117 TITLE: Infrared (IR) Optical Windows for Hypersonic Aerial Vehicles

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR);Hypersonics;Microelectronics

TECHNOLOGY AREA(S): Materials / Processes

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Design and develop infrared (IR) optical windows that are capable of protecting IR optical sensors and ensuring high-performance sensing during a hypersonic flight.

**DESCRIPTION:** Hypersonic aerial vehicles require the use of IR windows to protect sensitive optoelectronics from the aggressive aerothermal environment of high-speed flight while providing transparency to the IR optical signal used for intelligence, surveillance, reconnaissance, guidance, and communication applications [Ref 1]. The high temperatures of 3000 °F (1649 °C), or higher, associated with aerothermal impact of a high-speed/hypersonic vehicle during hypersonic flight, pose very challenging operating environments for the window material [Ref 2]. The interface surface or window material must be able to withstand extreme thermal, mechanical, and chemical environments during hypersonic flight that can limit the performance of the IR window and the IR sensor platform [Ref 3]. Furthermore, shock waves and extremely high heat loads produced during flight adversely impact wavefront distortions, and for this reason, affect the fidelity and accuracy of the signal/image detected by the optical sensors. Aerothermal-mechanical loads also create additional thermal requirements for the window to protect and insulate the sensor from the vehicle's extreme exterior condition [Ref 4].

The Navy requires development and demonstration of a new class of IR windows that can operate at extreme conditions of high-heat fluxes and high-air pressures, and enable high-performance optical sensing during hypersonic flights. The key performance parameters for the windows include:

- (a) wavelengths of interest: short-wave infrared (SWIR) – 1.4 to 3  $\mu\text{m}$  mid-wave infrared (MWIR) – 3 to 5  $\mu\text{m}$ , and long-wave infrared (LWIR) – 8 to 14  $\mu\text{m}$ ;
- (b) meet aerothermal and pressure loading conditions for hypersonic aerial vehicles;
- (c) accommodate both flat and non-flat (conformal, ogive, faceted) surface shapes to match vehicle aerodynamic design;
- (d) maintain electromagnetic and thermo-mechanical properties associated with the intended optical sensor during hypersonic flight;
- (e) window must endure the high temperatures (3000 °F [1649°C] or higher) and high-dynamic pressures (up to 12,000 lb/ ft<sup>2</sup>) (5,443.2 kg/0.0929 m<sup>2</sup>) during hypersonic flight;
- (f) the optical materials and designs of the windows should have minimum transmission loss in the desired wavelength bandwidths for each of the IR bands during hypersonic flight conditions.

**PHASE I:** Develop, design, and demonstrate the feasibility of candidate materials for window application through material properties testing. Research and select the IR window candidate materials for each of the IR wavelength band. The testing should include optical transmissivity, structural strength, and thermal properties of the window materials. Use modeling and simulation to estimate the thermal-optical and elastic-optical effects of the window materials and the impacts on transmission amplitude and bandwidth

## VERSION 5

during hypersonic flight. Provide a Phase II plan to develop and test the optical windows in accordance with their performance goals and key technical milestones while addressing technical risks and challenges discovered from the modeling and simulation in Phase I. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Fabricate the optical windows according to the fabrication plan laid out in Phase I. Perform comprehensive tests and evaluations of the fabricated candidate windows regarding their performance and reliability in a relevant hypersonic environment. Iterate the design/fabrication steps to modify the designs and fabrications of the optical windows due to technical challenges discovered in the test and evaluation phase to close the gaps in the performance and survivability endurance gaps.

PHASE III DUAL USE APPLICATIONS: Finalize development based on Phase II results, for transition and integration of the product into a hypersonic vehicle candidate airframe. Conduct flight test units for fielding on Navy experimental flight tests.

Potential commercial applications could include the applications of this research for infrared optical windows for commercial hypersonic re-entry vehicles.

### REFERENCES:

1. Chan, C. B. and Singh, N. "Calculation of refractive index around a hypersonic vehicle with infrared sensors." Proceedings IEEE Southeastcon'92, April 1992, pp. 562-565. <https://doi.org/10.1109/SECON.1992.202416>.
2. Di Clemente, M.; Rufolo, G.; Ianiro, A. and Cardone, G. "Hypersonic test analysis by means of aerothermal coupling methodology and infrared thermography." AIAA journal, 51(7), 2013, pp. 1755-1769. <https://doi.org/10.2514/1.J052234>.
3. Wan, Z. "Calculating models of cooling IR window and window background radiation." International Society for Optics and Photonics, Targets and Backgrounds: Characterization and Representation IV, Vol. 3375, July 7, 1998, pp. 195-202.. <https://doi.org/10.1117/12.327171>.
4. Krell, A.; Baur, G. M. and Dahne, C. "Transparent sintered sub- $\mu\text{m}$  Al<sub>2</sub>O<sub>3</sub> with IR transmissivity equal to sapphire." International Society for Optics and Photonics, Window and Dome technologies VIII, Vol. 5078, September 2003, pp. 199-207. <https://doi.org/10.1117/12.485770>.

KEYWORDS: Hypersonic; Optical Window; Infrared; IR; mid-wave infrared; MWIR; short-wave infrared; SWIR; long-wave infrared; LWIR; Wavefront Distortion; Aerothermal; Thermal-optical

# VERSION 5

N212-118 TITLE: Integrated Low-Jitter Mode-Locked Source for Optical Signal Processing Applications

RT&L FOCUS AREA(S): Microelectronics

TECHNOLOGY AREA(S): Air Platforms;Electronics

OBJECTIVE: Develop a compact, low-timing jitter, semiconductor mode-locked for optical signal processing applications.

DESCRIPTION: Emerging optical signal processing methods utilize the broadband nature of the optical spectrum to perform radio frequency (RF) signal processing in the optical domain. Examples of this include time-stretch analog analog-to-digital converters [Ref 1], photonic sampling [Ref 2] and the use of optical speckle to perform compressive RF sensing [Ref 3]. Both applications require pulsed optical sources with a wide wide-optical envelope and low low-timing jitter. To date, fiber-based mode-locked lasers [Ref 4] have been used for this application and have met the performance requirements for these applications such as ultra wideband electronic warfare receivers. To allow a reduction of size and power of these emerging optical signal processing techniques, there is a need to develop compact (on the order of 100 cubic centimeters (cc), efficient semiconductor sources that can be chip-scale integrated in compact implementations, and can meet the requirements for implementation on size-and-power constrained Navy platforms. The developed source must be compatible with further integration of additional functionality such as analog optical modulators and low-loss optical waveguides. The mode-locked optical source should operate in the 1.5-micron band with average output power exceeding 10 milliwatts (mW). The pulse repetition rate should be in the 10-100 megahertz (MHz) range, with pulse timing jitter less than 100 femtoseconds (fs), and an optical envelope exceeding 10 nanometers (nm).

PHASE I: Develop, design, and demonstrate the feasibility of an approach for a mode-locked or pulsed optical source that operates in the 1.5 micron  $\mu$  band with average output power exceeding 10 milliwatts (mW), 10-100 MHz pulse repetition rate, pulse timing jitter less than 100 fs, and an optical envelope exceeding 10 nanometers (nm). Develop a model for an optical signal processing system of interest for the Navy. Develop further application--specific requirements specifications for the mode-locked source. Through simulations or practical supporting measurement show that the proposed optical source will meet these requirements. The Phase I effort will include prototype plans to be developed under Phase II.

PHASE II: Fabricate and demonstrate a laser source that meets requirements defined in Phase I. Develop a prototype packaged laser demonstrator. Ensure, that at the end of Phase II, this packaged laser should be at Technology Readiness Level (TRL) 4 [Ref 5], with performance measured in a laboratory environment.

PHASE III DUAL USE APPLICATIONS: Complete development, perform final testing, and integrate and transition the final solution to future naval airborne electronic warfare and wideband radar systems.

As pointed out in the Description, this technology can be applied to time-stretch analog-to-digital converters, photonic sampling and the use of optical speckle to perform compressive RF sensing.

## REFERENCES:

1. Valley, G. C. "Photonic analog-to-digital converters." Optics Express, 15(5), 2007, pp. 1955-1982. <https://doi.org/10.1364/OE.15.001955>.
2. Misra, A., Kress, C., Singh, K., Preußler, S., Scheytt, J. C. and Schneider, T. "Integrated source-free all optical sampling with a sampling rate of up to three times the RF bandwidth of silicon photonic MZM." Optics Express, 27(21), 2019, pp. 29972-29984. <https://doi.org/10.1364/OE.27.029972>.

## VERSION 5

3. Sefler, G. A., Shaw, T. J. and Valley, G. C. “Demonstration of speckle-based compressive sensing system for recovering RF signals.” Optics express, 26(17), 2018, pp. 21390-21402. <https://doi.org/10.1364/OE.26.021390>.
4. Kim, J. and Song, Y. “Ultralow-noise mode-locked fiber lasers and frequency combs: principles, status, and applications.” Advances in Optics and Photonics, 8(3), 2016, pp. 465-540. <https://doi.org/10.1364/AOP.8.000465>.
5. Research Directorate, Defense, Research and Engineering (DDR&E). “Technology readiness assessment (TRA) Deskbook. Department of Defense, July 2009, pp. C-4-C-5. <http://www.acqnotes.com/Attachments/Technology%20Readiness%20Assessment%20Deskbook.pdf>.

KEYWORDS: Low jitter Lasers; Mode Locked Lasers; Photonic Sampling; Optical Speckle; Direct RF Conversion; Optical Compressive Sensing

# VERSION 5

N212-119 TITLE: Mobile User Objective System Dynamic Scanning Improvement

RT&L FOCUS AREA(S): Space

TECHNOLOGY AREA(S): Electronics;Space Platforms

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop a second-generation spectrally adaptive dynamic scanning algorithm to improve Mobile User Objective System (MUOS) Wideband Code Division Multiple Access (WCDMA) capable terminal UHF transmission efficiency and co-sharing spectrum supportability.

**DESCRIPTION:** As with any Department of Defense (DoD) radio system, radio frequency spectrum is shared and there is always the increased possibility of mutual or co-site interference. For MUOS capable radios, there are three types of interference mitigated by Spectrum Adaptation (SA): first, the MUOS radio transmission interference with the reception of non-MUOS radios (commonly called victims); second, interference to the satellite caused by other ground-based radios operating in the MUOS radio uplink frequency bands; and third, interference with the MUOS radio reception caused by non-MUOS radios operating locally within the MUOS radio's receive carrier.

The principal approach to defining interference limits within the Ultra High Frequency (UHF) bands is defined in the National Telecommunications and Information Administration (NTIA) Redbook. Typical narrow band radios have an equivalent isotropically radiated power (EIRP) in the 10 to 100 watt range. Applying the National Telecommunications and Information Administration (NTIA) Redbook criterion, the required out-of-band emission must be in a range no greater than -25dBW to -15dBW, with spurious emissions no larger than -43dBW. Narrow band radios must comply with this Spectral Emission Mask to avoid having additional coordination requirements imposed upon it.

Currently, the MUOS spectrally adaptive waveform transmits in the UHF (300 MHz – 320 MHz) band (20 MHz with 5 MHz distinct and separate channel) – equivalent to multi-carrier WCDMA. To avoid and protect other users within the transmitted band, the MUOS waveform is designed with the capability to scan the transmitted band, determine the presence of a victim signal (based on the pre-determined threshold), and then create RF masks in the amplifier and mask out the transmitted band. The algorithm employed in this case is a modified Discrete Fourier Transform (mDFT) using a polyphaser filterbank technique [Ref 1] and amplified further [Ref 2].

The envisioned second-generation spectrally adaptive algorithm would improve the frequency resolution, achievable notch depth, minimum notch bandwidth, computation cost, and design flexibility. From there, the algorithm would be implemented into a design suitable for incorporation with the MUOS waveform software. The goal for notching bandwidth is to reduce it to 25 kiloHertz or smaller per bin. The goal for notch depth is at least 27 decibels with an objective of 30 or more. The improved notching capability must require the same or less computational complexity in order to allow for software-only updates to existing radios.

## VERSION 5

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and NAVWAR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Create an initial conceptual design for a second-generation spectrally adaptive dynamic scanning algorithm. Predict performance using modeling and simulation or other tools. Consider radio integration issues. Estimate the power requirements and improved notch depth effectiveness. Determine the feasibility of the proposed approach to develop the algorithm to improve notch depth and scanning efficiency for MUOS radios. Develop a Phase II plan.

PHASE II: Build a prototype algorithm and simulate/test it in the spectrum-congested environment. Evaluate measured performance characteristics versus predictions from Phase I and make design adjustments as necessary. Develop a Phase III commercialization plan.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Support the integration of the design into the existing MUOS waveform. Support interoperability testing with existing systems in a lab and through end-to-end system test.

The technology developed under this SBIR topic may be applied to a variety of SATCOM and other spectrum dependent communication systems that are currently in development.

### REFERENCES:

1. Spooner, M.C. "Filterbanks for Adaptive Transmit Filtering." MILCOM 2007 - IEEE Military Communications Conference, Orlando, FL, USA, 2007, pp. 1-8. <https://ieeexplore.ieee.org/document/4455185>.
2. Commerce Spectrum Management Advisory Committee. "Interference and Dynamic Spectrum Access Committee, Interim Report, May 19, 2010." [https://www.ntia.doc.gov/files/ntia/meetings/csmac\\_may19\\_idsa\\_final.pdf](https://www.ntia.doc.gov/files/ntia/meetings/csmac_may19_idsa_final.pdf).

KEYWORDS: Mobile User Objective System; MUOS; Wideband Code Division Multiple Access; WCDMA; satellite; communications; cellular; 3G; adaptive algorithm; Spectrum Adaptation; SA; Ultra High Frequency; UHF; modified Discrete Fourier Transform; mDFT; polyphaser filter



# VERSION 5

N212-120 TITLE: Development of Non-Toxic but BioFouling Deterrent Marine Coatings

RT&L FOCUS AREA(S): Autonomy;General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Ground / Sea Vehicles;Materials / Processes

OBJECTIVE: Develop marine coatings that deter the settlement of biofouling without relying on the release of toxic chemicals. The coatings must not rely on an external source for activation (i.e., mechanical, optical, chemical) and must be practical for application on the large surface areas of the wetted ship hull.

DESCRIPTION: Marine antifouling coatings use biocides to minimize biofouling on ship hulls and are thus a compromise in terms of being environmentally beneficial (e.g., maximizing fuel efficiency, minimizing introduction of non-indigenous species) and environmentally harmful (i.e., releasing toxins). Current coatings either have an ablative matrix that the biocides diffuse through or are self-polishing and slowly hydrolyze to release the biocides. When the biocide release rate drops below a threshold, hard foulers such as barnacles can strongly adhere to the ship hull. Alternative "fouling release" coatings have been developed, which do not release biocides and operate as easy to clean coatings which may self-clean by the shear of water against the hull when moving or be easily cleaned with soft brushes or wiping with a sponge. These coatings are generally based on silicone resins sometimes enhanced to present hydrophilic or amphiphilic domains on the immersed coatings surface. However, when ships are idle in port, biofouling can quickly accumulate to the extent that it will not self-clean. This is problematic for the Navy so most ships use antifouling coatings.

Commercial marine coatings manufacturers have started to develop hybrid coatings in which biocides are added to fouling release matrices. In some ways, these represent the best of both worlds, but it is doubtful that these coatings will retain these biocides to provide a long coating lifetime. Also, in the long run, non-toxic approaches are desired.

The goal of this SBIR topic is to develop environmentally benign coatings that deter settlement without the release of biocides, are effective for five years or more, and are easy to clean should some biofouling occur. To compete with antifouling coatings from a cost/performance perspective, such approaches should not resort to expensive active mechanisms involving electrical, thermal, mechanical, or optical stimulation. There are several approaches to achieve this in the literature, though currently none are fully successful so more development is necessary. The challenge is that the breadth and diversity of the marine biofouling community is high and extends from microscopic to macroscopic (i.e., bacterial to algae and barnacles), though stopping the initial foulers is a good approach. One strategy is to tether the biocides to the coating surface. Efficacy in this approach may depend on the inhibition mechanism of the biocide, and also whether cell debris is easily dislodged enabling the biocide to remain effective [Ref 1]. Another approach involves creating hydrophilic or amphiphilic surfaces using zwitterions. In general, this approach results in easy release surfaces but some methods of presenting the zwitterions seem to make the surfaces deterrent [Ref 2]. Though it is less desirable to release chemicals, registered irritant compounds such as Selektope which could provide a non-toxic coating. Researchers have also investigated release of various biofoulant signaling compounds [Ref 3]. Other novel approaches are welcome.

PHASE I: Develop approaches to producing coatings that are easy release and deter biofouling settlement relative to control surfaces (e.g., glass, polydimethylsiloxane (PDMS), commercial fouling release coating (Navy can identify relevant coatings) without releasing toxic compounds. Demonstrate this capability in lab assays against marine fouling on various fouling levels including marine bacteria, algae, and possibly invertebrates such as barnacles or tubeworms. Performers can use their own lab assays and/or submit samples to the ONR basic research program in this area [Ref 4]. Performers that use their own assays will



## VERSION 5

need to calibrate them against the ONR assays. (ONR assays are generally carried out on coated microscope slides and coverslips.)

PHASE II: Scale coating for testing of coated 4 inch by 8 inch substrates in static field assays at ONR funded facilities. Optimize coating based on iterations of lab assay characterization and field testing. Optimize coating for longer term performance. Provide a business plan to commercialize coating.

PHASE III DUAL USE APPLICATIONS: Scale coating for patch testing on a Navy ship. Execute commercialization strategy for commercial and defense applications. The Navy currently utilizes coatings developed for commercial shipping which pass additional Navy qualification tests.

### REFERENCES:

1. Park, Daewon; Finlay, John A.; Ward, Weinman, Craig J.; Krishnan, Sitaraman; Paik, Marvin; Sohn, Karen E.; Callow, Maureen E.; Callow, James A.; Angert, Esther R.; Kramer, Edward J. and Ober, Christopher K. "Antimicrobial Behavior of Semifluorinated-Quaternized Triblock Copolymers against Airborne and Marine Microorganisms." *Applied Materials and Interfaces*, 2(3), 210, pp. 703-711.
2. Aldred, Nick; Li, Guozhu; Gao, Ye; Clare, Anthony S. and Jiang, Shaoyi. "Modulation of barnacle (*Balanus amphitrite* Darwin) cyprid settlement behavior by sulfobetaine and carboxybetaine methacrylate polymer coatings." *Biofouling*, 26:6, 2010, pp. 673-683.
3. Gohad, N.V.; Shah, N.M.; Metters, A.T.; and Mount, A.S. "Noradrenaline deters marine invertebrate biofouling when covalently bound in polymeric coatings." *Journal of Experimental Marine Biology and Ecology*, Volume 394, Issues 1-2, 30 October 2010, pp. 63-73.
4. Stafslie, Shane J.; Sommer, Stacy; Webster, Dean C.; Bodkhe, Rajan; Pieper, Robert; Daniels, Justin; Vander Wal, Lyndsi; Callow, Maureen C.; Callow, James A.; Ralston, Emily; Swain, Geoff; Brewer, Lenora; Wendt, Dean; Dickinson, Gary H.; Lim, Chin-Sing; and Teo, Serena Lay-Ming. "Comparison of laboratory and field testing performance evaluations of siloxane-polyurethane fouling-release marine coatings." *Biofouling*, 32:8, 2016, pp. 949-968.

KEYWORDS: antifouling coatings; fouling release coatings; biocides; non-toxic

# VERSION 5

N212-121 TITLE: Improved Marx Pulse Generator for High Power Microwave (HPM) Systems

RT&L FOCUS AREA(S): Directed Energy (DE)

TECHNOLOGY AREA(S): Electronics;Ground / Sea Vehicles;Weapons

OBJECTIVE: Develop a sub-10 nanosecond rise time, GW-class Marx generator with long-lifetime insulated spark gap switches with preferred air (or other gas) as the primary insulation medium to support the deployment of next-generation HPM weapons.

DESCRIPTION: High power microwave (HPM) systems frequently require high voltage, high current, nanosecond duration pulses in order to generate radio frequency (RF) signals [Ref 1]. Such pulses are frequently generated by Marx generators [Refs 2, 4], which consist of multiple stages of capacitors charged in parallel and rapidly connected in series, usually by gas spark gap switches [Ref 5], to boost the voltage and provide an output pulse [Ref 6]. The spark gap switches consist of at least two electrodes, often contained within a high-pressure body filled with gas, and often utilize a trigger electrode situated between the two primary electrodes. A high voltage pulse is sent to the trigger, which breaks down to one of the primary electrodes, causing breakdown between both primary electrodes, thereby electrically connecting stages in series. Several failure mechanisms exist for these switches, making lifetime and maintenance a frequent issue. This is particularly true when compact designs are required. Problems include surface tracking between electrodes along the body of the switch and electrode erosion. High repetition rates can also be problematic, as gas flow is required to clear ionization and heat from previous shots. If sufficient gas purging is not accomplished between shots, thermal damage may be incurred or hold-off decreases, allowing breakdown to occur before full voltage is achieved [Ref 7].

Meanwhile, the Marx stages must be insulated from each other, which is usually accomplished with gas or transformer oil. In compact Marx generators, oil is often the insulator of choice due to its superior voltage hold-off qualities at Standard Temperature and Pressure (STP). However, oil insulation creates several issues. First, the use of insulating oil complicates Marx maintenance in deployed environments because of onerous drain and fill processes and OCONUS supply chain challenges. Second, high pressure switches leak into the oil at finite rates. Gas leakage occurs through switch body or gas fitting failures or by gas diffusion through the switch body and routing lines over long-term depot storage periods. Gas leaking into the oil results in dissolved gas or bubbles that significantly reduce the voltage insulating capability of the oil, and can cause ill-formed pulses or catastrophic failure of the Marx. Finally, oil insulation may result in Marx designs heavier than those insulated by gas.

A compact, fast rise time Marx design that utilizes air as its insulation and long life gas switches is therefore desired.

## KEY MARX GENERATOR PARAMETERS:

- 300 kV peak pulse voltage or more into a matched load
- 13-20  $\Omega$  (ohm) output impedance
- 10 ns 10 – 90% voltage rise time or less
- 15 – 50 ns FWHM
- Threshold 10,000 / Objective 50,000 shot lifetime without maintenance or better
- 0.50 m diameter or smaller
- 1.25 m length or smaller
- Threshold 50 Hz / Objective 300 Hz repetition rate for 10 shots every 2 seconds for 5 bursts, or better
- 200 kg weight or less
- Air insulated (or other gases such as SF<sub>6</sub> replacement mixture)

## VERSION 5

- Tolerant of up to 40% reversal of the output

PHASE I: Develop a concept for a compact Marx generator meeting the above Key Parameters that utilizes air as its insulation medium for both the switch and primary Marx insulation. Simulate switch electrostatics, and establish switch-purging methodology. Simulate Marx pressure vessel hydrostatics and electrostatics. Prepare a report to ONR and AFRL on designs and simulations and a Phase II testing plan.

PHASE II: Fabricate switch design(s) developed during Phase I for high voltage and pressure testing and gas flow analysis. These tests are to be performed under the temperatures outlined in MIL-STD-810H Test Methods 501.7 (Hot Dry) and 502.7 (Basic Cold). Measure switch lifetime under representative conditions and refine design as necessary to meet Key Parameters. Fabricate Marx pressure vessel and test at pressure. Provide switch prototype, Marx pressure vessel prototype, and report containing designs and testing results, and a Phase III plan to ONR/AFRL/NSWCDD for prototype evaluation.

PHASE III DUAL USE APPLICATIONS: Assemble full gas-insulated Marx generator and demonstrate output meeting Key Parameters. Demonstrate full Marx lifetime operating into a matched load. Deliver Marx prototype and a report containing designs and testing data to ONR/AFRL/NSWCDD. The development of a compact, high reliably pulsed power system would expand the present state of the art for Directed Energy and enable component level exploitation for commercial applications in the pulsed power industry.

### REFERENCES:

1. Korovin, S. D. et. al. "Pulsed Power-Driven High-Power Microwave Sources." Proc. of the IEEE, Vol. 92, No. 7, 2004.
2. Walterx, J. et. al. "An "energy efficient" vircator-based HPM system." 2011 IEEE Pulsed Power Conference. DOI 10.1109/PPC.2011.6191558.
3. Sharma, A. et. al. "Development and Characterization of Repetitive 1-kJ Marx-Generator-Driven Reflex Triode System for High-Power Microwave Generation." IEEE Trans. On Plasma Science, Vol. 39, Issue 5, May 2011.
4. Pouncey, J.C.; Lehr, J.M.; and Giri, D. V. "Erection of Compact Marx Generators." IEEE Transactions on Plasma Science, vol. 47, no. 6, June 2019, pp. 2902-2909. doi: 10.1109/TPS.2019.2915034.
5. Pouncey, J.C. and Lehr, J. M. "A parametric SPICE model for the simulation of spark gap switches." Rev. of Sci. Instr., 91, 034704, 2020.
6. Fitch, R. and Crewson, W. "Marx generator and triggering circuitry therefor." US3746881A, United States Patent and Trademark Office, 17 July 1973.
7. Winands, G. J. J. et. al. "Long lifetime, triggered, spark-gap switch for repetitive pulsed power applications." Rev. of Sci. Instr., 76, 085107, 2005.

KEYWORDS: High Power Microwaves; Marx Generator; Spark Gap Switches; HPM; Marx; Pulsed power

# VERSION 5

N212-122      TITLE: Characterizing 5G vulnerabilities in an expeditionary environment

RT&L FOCUS AREA(S): 5G;Cybersecurity

TECHNOLOGY AREA(S): Information Systems

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop a lightweight and reliable vulnerability detection and verification system for 5G end user devices and its supported infrastructure at the Physical (PHY) and Media Access Control (MAC) layers.

**DESCRIPTION:** The Navy seeks development of a lightweight and reliable vulnerability detection and verification system for 5G end user devices and its supported infrastructure at the Physical (PHY) and Media Access Control (MAC) layers.

The general architecture for 5G networks demonstrates the ability to connect to many differing types of devices such as high speed mobile networks, vehicular networks, and industry machine-to-machine communications. The throughput, latency, and bandwidths not only appeal to every day users but to military operations that seek to become more connected. However, little is understood how the vendors will implement the security features provided in the 3GPP R16 specification [Ref 4]. Due to the diversification of the emerging commercial lines, it is likely that each 5G network will exhibit very different security stances.

The objective is to develop a prototype device that can perform integrity checks and vulnerability discovery actions upon entry into prototypical 5G networks (e.g., vehicular networks, smart communities, healthcare networks). The device will focus on assessing security issues with the media access control (MAC) layer and physical (PHY) layer and providing users that feedback. Major attacks that threaten wireless networks include eavesdropping, jamming, denial-of-service, and man-in-the-middle. Emerging work in protocol fuzzing and protocol reverse engineering provides higher order effects even on proprietary systems. Many of these approaches are difficult under ideal situations.

The prototype device must be able to demonstrate the ability to be deployed in an expeditionary setting. The system should be able to be operated using a power draw from a medium sized tactical vehicle (i.e., JLTV). It should not exceed 100 lbs for easy transport and its dimensions should not warrant larger than a 2-man carry.

Security and privacy studies have focused on earlier generation wireless networks. Only in the last couple of years has a systematic approach to looking at vulnerability discovery for 4G Long Term Evolution (LTE) been published. 5G presents a heavier reliance on virtualization and software-defined networking. The impact of this on security has not yet been fully grasped. These impacts must be understood at the sub-6GHz and the mmWave bands.

## VERSION 5

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances. This will allow contractor personnel to perform on advanced phases of this project as set forth by DCSA and ONR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

**PHASE I:** Define and develop a concept to meet Naval needs for an innovative and mobile 5G vulnerability detection reporting capability. Evaluate the technical feasibility of this concept for the Naval Forces. Perform modeling and simulation to provide initial assessment of concept. This will include network architectures likely to be encountered in expeditionary environments (see MCTP 3-40G), the attack vectors, and security features expected. Initial system design parameters to perform assessments will also be derived.

**PHASE II:** Develop a Phase II prototype for evaluation based on the results of Phase I. The prototype will be evaluated to determine its capability in meeting the performance goals defined in Phase II Statement of Work (SOW) and the Naval need for improved security via integrity assessment of nearby local 5G networks that could be leveraged for military operations. Knowledge of which networks are reliable could be disseminated to service members using personal devices in forward deployed zones to increase operational security. Demonstrate the ability to discover vulnerabilities across the PHY and MAC layers (threshold) as well as higher in the stack (objective) and present this data to users. Showcase this ability over various differing network use case configurations. The prototype design should be at least of a vehicle mount configuration. Deliver a minimum of three prototypes to the Navy for evaluation. Perform detailed analysis to ensure the materials are rugged and appropriate for Naval application, including environment, shock, and vibration analysis.

Phase II may become classified (see Description) with the discovery of vulnerabilities within the PHY and MAC layers of signals of interest to the Naval Forces. In those cases, surrogates as well as the specific signals of interest will be evaluated.

**PHASE III DUAL USE APPLICATIONS:** Apply the knowledge gained in Phase II to build an advanced module, suitably packaged with arbitrary waveform generation, ability to either self-power or connect with a vehicle plant, and to characterize the local 5G network to include its vulnerabilities as defined by Naval requirements. Working with the Navy and applicable industry partners, demonstrate application with the potential to be implemented on a light tactical vehicle and/or at a land-based test site to support vulnerability discovery and reporting. Support the Navy with test and validation to certify and qualify the system for Naval use. Explore the potential to transfer the vulnerability discovery tool to other military and commercial systems (e.g., telecommunications). Identify the most promising areas via market research and analysis and develop manufacturing plans to facilitate a smooth transition to the Navy.

5G is an emerging network that is gaining traction across the entire global market. As users share more and more content online, security and privacy will become a larger concern. Providing a means to understand network integrity will aid users in data transfer decisions and potentially reduce catastrophic vulnerability and economic impacts.

**REFERENCES:**

## VERSION 5

1. Fang, Dongfeng; Quan, Yi; and Hu, Rose Qingyang. "Security for 5G Mobile Wireless Networks" IEEE Access Special Section on Trusted Computing Vol 6, 2019.
2. Bartock, Mike; Cichonski, Jeff; and Souppaya, Murugiah. "5G Cybersecurity: Preparing a Secure Evolution to 5G." NIST National Cybersecurity Center of Excellence, April 2020.
3. Hussain, Syed Rafiul; Chowdhury, Omar; Mehnaz, Shagufta; and Bertino, Elisa. "LTE Inspector: A Systematic Approach for Adversarial Testing of 4G LTE." Network and Distributed Systems Security (NDSS) 2019, 18-21 February 2019, San Diego, USA.
4. 3GPP Release 16. July 2020. <https://www.3gpp.org/release-16>.

KEYWORDS: Wireless networks; security and privacy; network architecture; attack models; 5G; vulnerability discovery

# VERSION 5

N212-123      TITLE: External Payload Deployment System for Cylindrical UUVs

RT&L FOCUS AREA(S): Autonomy;Microelectronics;Networked C3

TECHNOLOGY AREA(S): Ground / Sea Vehicles;Sensors;Weapons

OBJECTIVE: Develop an external payload deployment system for cylindrical unmanned underwater vehicles (UUVs. Example payloads may be sensors, markers, or communications relays. The system will not interfere with the operation of the UUV and will respond to UUV commands to detach and activate.

DESCRIPTION: There are many UUV missions that would benefit from leave-behind technology. However, the UUV market is dominated by cylindrical UUVs, making development of an external payload deployment system technically challenging. Despite the technical difficulties involved, the potential for UUV navigation, communication, environmental monitoring, and surveillance payloads make this SBIR topic a worthwhile endeavor. The main technical challenge is that such a system will modify the hydrodynamic behavior of the host UUV and will therefore affect its controllability and maneuverability. Another important technical challenge is minimally invasive command and control communications between the UUV and the external payload.

Most current UUVs cannot leave behind useful technology when they encounter something of interest. In many retrieval scenarios, precisely placing an acoustic beacon would aid the following retrieval mission normally undertaken with work class Remotely Operated Vehicles (ROVs). In another scenario, placing a communications relay, where underwater communications starts to degrade, would avoid the loss of communications with a vehicle. In yet another scenario, leaving a trail of small markers may aid feature-based navigation in featureless environments. For these scenarios, the most versatile and fastest integration approach would be to mount an external payload onto the vehicle and have this payload receive instructions without having to make physical connections to the vehicle's systems.

Technology proposed under this effort should develop an external payload for cylindrical UUVs up to 21" in diameter that minimizes interference with UUV hydrodynamics and vehicle control while limiting reduction to mission endurance. Additionally, the payload should communicate with the UUV payload computer using connections that do not pierce the UUV hull. Proposers should also understand and demonstrate the flight stability of the payload when dropped, and determine the accuracy of the deployment relative to the intended location. The design must have a robust buoyancy compensation system for the payload such that the changes to the UUV's Center of Gravity and Center of Buoyancy are not detrimental. Deployment should be effective over a limited range of UUV altitudes and speeds (less than 5 m altitude and speed of less than 5 m/s).

## DESIGN CRITERIA:

- UUVs Under Consideration: Cylindrical main body with a diameter of between 5 and 21 inches and length less than 20 ft.
- Buoyancy: Neutral when attached to UUV / Negative when detached from UUV
- Hydrodynamic Forces: Should not appreciably change UUV Center of Gravity or Center of Buoyancy and not require UUV controller modification
- Communications: no through-hull modifications
- Detachment: on-command from UUV
- Payload drop accuracy: determined by program @ UUV min speed: 1 m/sec and UUV min depth 3 m
- Parasitic drag after release: minimal less than 10% over unmodified vehicle drag



## VERSION 5

- Payload drag (before or after detachment): should not decrease UUV mission time by more than 25%
- Adaptable buoyancy in variety of seawater densities – including freshwater
- Anticipate standard mil spec environment, shock, vibration, transportability testing in Phase II/III
- Carry load: module that weighs up to 5 kg in air

Testing for standard mil spec compliance (environment, shock, vibration, and transportability) will occur in Phase II and III.

PHASE I: Demonstrate the feasibility of a concept for an external UUV payload that satisfies the previously listed design criteria for a cylindrical vehicle. Smaller diameters than the 5 inches in the design criteria can be proposed, as long as there is evidence that the payloads would provide a useful function. Analysis on initial hardware and software concepts will be completed to determine the optimal design and feasibility in the projected use case. Either modeling using semi-empirical methods [Refs 1, 4, 5] and simulations [Refs 2, 3] or in-water tests will be performed to justify the approach. An analysis will also be made of the most effective command and control communication approach that will not require perforation of the UUV hull. Develop a Phase II plan.

PHASE II: Develop and fabricate two to three prototype systems for evaluation. Precise evaluation metrics will be developed in consultation with the appropriate acquisition program office. The prototype demonstration should show applicability to current UUV form factors and mission requirements. Perform detailed analysis on ruggedness and compatibility with Navy UUV handling, storage, and environmental operating conditions. Testing will be conducted by both the performer and by Navy personnel on Navy assets. Cost effectiveness and manufacturability feasibility should be addressed as part of the prototype test and evaluation.

PHASE III DUAL USE APPLICATIONS: Applying the knowledge gained in Phase II, build an advanced UUV payload system that meets appropriate technology readiness level (TRL) metrics set by the acquisition program office. Support the Navy for test and validation of the system for certified Navy use. Explore the potential to transfer the payload delivery system to commercial use (e.g., oil and gas industry). Develop manufacturing plans to facilitate transition to a UUV program of record.

### REFERENCES:

1. Severholt, J. "Generic 6-DOF Added Mass Formulation for Arbitrary Underwater Vehicles based on Existing Semi-Empirical Methods." Master's Thesis, Royal Institute of Technology of Sweden, June 20, 2017.
2. Liu, A.; Chen, G.; Feng, J. and Hu, J. "Research on the Hydrodynamic Characteristic of Conformal Semi-Ring Wing Configuration." 2017 International Conference on Computer Systems, Electronics and Control (ICCSEC), pp. 78-82.
3. Zhou, J. and Wang, S. "Dynamics Modeling and Maneuverability Simulation of the Unmanned Underwater Vehicle Hanging Torpedoes Externally." 2009 International Asia Conference on Informatics in Control, Automation and Robotics, Bangkok, 2009, pp. 207-210.
4. Perrault, D. "Sensitivity of AUV added mass coefficients to variations in hull and control plane geometry." Ocean Engineering, vol. 30, April 2003, pp. 645-671.
5. Humphreys, D.E. and Watkinson, K.W. "Prediction of acceleration hydrodynamic coefficients for underwater vehicles from geometric parameters." Naval Coastal Systems Laboratory Tech Report NCSL 327-78, Panama City, Florida, 1978.

KEYWORDS: Unmanned underwater vehicle; UUV; payload, navigation, communication, surveillance, hydrodynamic forces

# VERSION 5

N212-124      TITLE: Low-cost Mid-wave Infrared Focal-Plane Arrays through Direct-on-Read Out Integrated Circuit Detector Fabrication

RT&L FOCUS AREA(S): Autonomy;Microelectronics

TECHNOLOGY AREA(S): Materials / Processes;Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop new detectors, bonding methods, or fabrication techniques for mid-wave infrared (MWIR) focal plane arrays that enable lower cost infrared imaging for navigation, object detection, collision avoidance, and force protection.

DESCRIPTION: Electro-Optic and Infrared (EO/IR) sensors are used in a wide variety of applications and missions such as long-range detection and identification of objects, seeing at night, and wide area surveillance. Although infrared offers superior imaging in most scenarios, visible sensors are more proliferated than IR due to the dramatically lower cost and higher pixel resolution available. IR sensors have higher costs compared to visible because of many system factors; this SBIR topic proposes to solve one of those factors: the focal plane array (FPA). The MWIR imaging band of 2.8  $\mu\text{m}$  to 5  $\mu\text{m}$  is used across the Naval forces for imaging targets in a wide range of atmospheric conditions. The goal is to develop novel MWIR FPA materials or processes to achieve > 20x cost reduction over existing MWIR FPAs.

In order to get an image out of the IR FPA, die-to-die bonding of the FPA to a read out integrated circuit (ROIC) is performed creating a sensor chip assembly (SCA). Multiple infrared imaging technologies are used today for the FPA [Ref 1] and most are now available at higher operating temperatures (HOT) (e.g., above 110 K). All of the highest performing FPAs are made from either group III-V or II-VI semiconductors [Ref 1, 2]. The IR-absorbing material chosen sets the limit on overall FPA size, pixel size, and cost. Some of these factors are directly related to the substrate (e.g., size and cost), while others are material and processing specific (e.g., pixel size). No matter what FPA material is chosen, the ROIC is always made in Silicon (Si) due to the low-cost manufacturing and superior electronics properties.

To accomplish the goal of a low-cost MWIR FPA, various strategies might be explored. One such method might be the use of IR-absorbing semiconductors that are compatible with Si-complementary metal oxide semiconductor (CMOS) processes. In this approach the absorber would be directly deposited (i.e., grown) on the Si wafer containing the ROIC-enabling large-scale batch processing directly on 200 mm or 300 mm Si CMOS wafers. Multiple material systems within this direct growth area have been explored previously that could be applied to this topic. Possible research directions include, but are not limited to, Group IV materials [Ref 3], III-V direct growth [Ref 4], and quantum dots [Ref 5]. Another such method outside of direct growth on Si is novel direct bonding methods of an FPA wafer to the Si ROIC. In this approach, the FPA active absorber material is grown on III-V or II-VI substrates, then subsequently bonded to the Si ROIC. All solutions should address yield and the ability to scale down to smaller pixels to meet future large format sensing requirements.

## VERSION 5

The solution should be a drop-in replacement to existing MWIR SCAs and thus should not require significant deviation in design to existing MWIR optics. If the solution requires cooling, then industry standard integrated dewar cooler assemblies (IDCA) or thermoelectric coolers should be used to maximize backwards compatibility.

End of program deliverable design characteristics:

- Specific detectivity ( $D^*$ ) of individual detectors/pixels within the 3  $\mu\text{m}$  to 5  $\mu\text{m}$  band: above  $10^{11}$  Jones [normalized to  $2\pi$  field of view (FOV) and 300 K background]
- Noise equivalent temperature difference (NETD) for imaging array: below 25 mK
- Quantum efficiency (QE) within the 3  $\mu\text{m}$  to 5  $\mu\text{m}$  band: shall be no less than 20% of the peak QE
- Peak QE: shall be between 3  $\mu\text{m}$  and 5  $\mu\text{m}$
- Detector cooling:  $\geq 110$  K
- Pixel size:  $\leq 10$   $\mu\text{m}$
- Frame rate:  $\geq 30$  fps
- Dynamic range:  $\geq 14$  bits

PHASE I: Develop a concept for new detectors, bonding methods, or fabrication techniques for MWIR FPAs that demonstrates the approach, while providing for design scalability for MWIR operation. This demonstration can be for a single-element detector or detector array, along with performance metrics, or demonstration of a direct bonding method.

- Identify major hurdles and physical limits of the approach that might include: dark current, 1/f noise, threading dislocations, thermal stress of dissimilar materials, etc.
- Reports and findings on the fabrication, growth, and tunability of the recipes to create a hardware prototype.
- Investigate, document, and select best-of-breed approaches to a low cost MWIR FPA.
- Test the prototype in a laboratory environment with a minimum of electrical read-out of the dark current and could include quantum efficiency.

PHASE II: Build, develop, demonstrate, validate, and mature the hardware.

- Improve detector level performance metrics such quantum efficiency, detectivity, dark current I-V, and spectral noise.
- Build a test chip carrier suitable for proof-of-concept demonstrations.
- Fabricate a small format FPA suitable for an imaging demonstration. Test chip can either be directly with a ROIC or read out element wise to show detector functionality.
- Test the prototype in a laboratory simulated operational environment and identify metrics to validate the system's advantages over state-of-the-art in MWIR imagers.
- Work with the Government to identify and develop a representative set of transition opportunities for early deployment of the developed concepts.
- Develop a transition plan for the Program of Record (PoR) and for commercial industries via a Phase III commercialization plan.

PHASE III DUAL USE APPLICATIONS: Apply the knowledge gained in Phase II toward the manufacture of a full frame imaging SCA at 640 x 480 or larger format.

- Build an imaging sensor and characterize its performance using imaging array level performance metrics such as modulation transfer function (MTF), QE, and noise equivalent temperature difference (NETD).
- Identify packaging and yield for transition to a PoR.
- Work with the Navy and applicable industry partners to demonstrate that the SCA can be readily, non-disruptively adapted to an existing EO/IR platforms and optics. Test the sensor in a representative environment (e.g., on a Navy-owned range) with conventional MWIR optics to measure performance comparable to existing state-of-the-art in MWIR cameras.

## VERSION 5

- Market research and analysis shall identify the most promising users across the Navy and/or commercial markets. Develop and document a methodology for smoothly integrating the capability onto identified platforms.

### REFERENCES:

1. Rogalski, A. "Recent progress in infrared detector technologies." *Infrared Physics & Technology*, 54(3), 2011, pp. 136-154.
2. Martyniuk, P. and Rogalski, A. "HOT infrared photodetectors." *Opto-Electronics Review*, 21(2), 2013, pp. 239-257.
3. Soref, R. "Group IV photonics for the mid infrared." *Proceeding SPIE 8629, Silicon Photonics VIII* 862902, 14 March 2013.
4. Tanabe, K. et al. "III-V/Si hybrid photonic devices by direct fusion bonding." *Scientific Reports* 2(1), Article: 349, April 2, 2012.
5. Rogalski, A. et al. "Comparison of performance limits of HOT HgCdTe photodiodes and colloidal quantum dot infrared detectors." *SPIE Defense + Commercial Sensing, SPIE Vol 11407*, April 23, 2020.

**KEYWORDS:** Focal plane array; FPA; infrared imaging; IR; semiconductor processing; read out integrated circuit; ROIC; sensor chip assembly; SCA; mid-wave infrared; MWIR; semiconductor materials

# VERSION 5

N212-125      TITLE: Mobile Electrocardiogram Monitor for Bottlenose Dolphins in the Marine Environment

RT&L FOCUS AREA(S): Biotechnology

TECHNOLOGY AREA(S): Biomedical;Electronics

OBJECTIVE: Develop a wearable, wireless electrocardiogram (ECG) unit to analyze and communicate heart rate and rhythm in bottlenose dolphins in the marine environment (i.e., salt water).

DESCRIPTION: The U.S. Navy uses bottlenose dolphins (*Tursiops truncatus*) in the Fleet's operational Marine Mammal Systems to protect harbors and Navy assets, detect and/or mark underwater mines, and locate and attach recovery hardware to underwater objects. To contribute to maintaining the fitness of these marine mammals for duty and the readiness of the U.S. Navy Marine Mammal Systems, the U.S. Navy is interested in developing a wearable, wireless ECG unit to monitor dolphin cardiac rate and rhythm while the animal is at rest and actively swimming in the marine environment. Synchronized information regarding the swimming depth of the animal is required.

With aging populations of marine mammals under professional care, cardiac disease is of increasing clinical concern. Over the years, the U.S. Navy Marine Mammal Program has diagnosed several dolphins with cardiac disease, particularly in geriatric animals. Developing improved cardiac monitoring techniques are vital to identifying and monitoring cardiac disease cases, supporting healthy aging, and enhancing dolphin cardiac medicine.

Due to their marine environment home, no clinically viable options for in-water ECG monitoring exist in bottlenose dolphins. Limitations include electrode signal interference from seawater, animal motion artifacts, and lack of wireless systems. Several studies have described ECG evaluation in cetaceans over the last two decades [Ref 1-6]. However, there are no commercially available units that allow for ECG recording while the dolphin is swimming or diving untethered. Electrodes are also very sensitive to interference from motion and seawater. Analyzing not only heart rate, but heart rhythm as well, while dolphins are free swimming will provide valuable data to drive clinical decision making and will be especially valuable in monitoring animals with known dysrhythmias. Examples of cardiac health issues in Navy dolphins leading to dysrhythmias have included dilated cardiomyopathy, valvular disease, and arrhythmias due to a variety of etiologies. This need for "in ocean" monitoring is significant because, while we are able to obtain ECG data with the animal out of the water, we do not fully understand the physiologic consequences that may be occurring with the animal out of its aquatic habitat, potentially confounding the ECG interpretation. The techniques that would be most reflective of true cardiac health will be best assessed while the animal is in the natural marine environment. This technique would also allow for cardiac event monitoring over longer periods of time, which may identify important dysrhythmias not evident in brief ECGs. As such, proposed concepts should generate a reliable, wireless, mobile ECG device for in-water recording in dolphins that can be used and evaluated by veterinarians to help maintain Navy dolphin health.

PHASE I: BASE period: Conceptualize, design, and build a prototype mobile ECG monitor for bottlenose dolphins. The mobile ECG monitor should be cordless and wearable, allowing dolphins to swim safely and freely in enclosures or the open ocean, up to 50m depth and at temperatures between 32-98 degrees F. The device should have 4-leads with 6 vector recordings (i.e., leads I, II, III, AVR, AVL, AVF). The device should be able to transmit ECG data in real time via Bluetooth to a laptop or tablet when worn at the surface or out of water; it should also be able to record and store ECG data when the dolphin is swimming or diving underwater for a minimum of 24 hours, which can then be transmitted or downloaded onto a laptop/tablet once the animal has returned from swimming or diving. Synchronized information on the depth the animal swimming is also required. Battery life should allow for several hours of recording at a time. The wearable

## VERSION 5

design, materials, and lead locations should be refined to create an optimal working prototype and allow for animal safety and comfort. To allow for future testing and refinement of the ECG unit, documentation required by the U.S. Navy to conduct research involving vertebrate animals should be completed and approval obtained. Collaboration with dolphin ECG experts and board-certified veterinary cardiologists is recommended.

OPTION period: Test and refine the prototype mobile ECG monitor for bottlenose dolphins.

PHASE II: Build an operable mobile ECG monitor with the technology developed in Phase I. Demonstrate/validate the operability and reliability of the system on bottlenose dolphins in the marine environment. Document and report the ECG findings of dolphins wearing the unit, and refine the technology for optimal use in terms of wearability (i.e., lack of physical harm or change in animal's behavioral or condition) and ECG quality (i.e., interpretable ECG trace with lack of artifacts, repeatability, and comparison to out of water measurements).

PHASE III DUAL USE APPLICATIONS: Efforts should lead to development of a product that meets appropriate standardization requirements and focuses on technology transition, preferably commercialization (i.e., marine mammal health management industry for zoos, aquariums, marine mammal parks, marine mammal conservation organizations, etc.; professional or recreational diving industry).

### REFERENCES:

1. Harms, C.A.; Jensen, E.D.; Townsend, F.I.; Hansen, L.J.; Schwacke, L.H. and Rowles, T.K. "Electrocardiograms of bottlenose dolphins (*Tursiops truncatus*) out of water: habituated collection versus wild postcapture animals." *J Zoo Wildl Med*, Vol. 44, December 31, 2013, pp. 972-981. doi:10.1638/2013-0093.1.
2. Yaw, T.J.; Kraus, M.S.; Ginsburg, A.; Clayton, L.A.; Hadfield, C.A. and Gelzer, A.R. "Comparison of a smartphone-based electrocardiogram device with a standard six-lead electrocardiogram in the Atlantic bottlenose dolphin (*Tursiops truncatus*)." *J Zoo Wildl Med*, Vol. 49, September 1, 2018, pp. 689-695. doi:10.1638/2017-0140.1.
3. Williams, T.M.; Fuiman, L.A.; Kendall, T.; Berry, P.; Richter, B.; Noren, S.R.; Thometz, N.; Shattock, M.J.; Farrell, E.; Stamper, A.M. and Davis, R.W. "Exercise at depth alters bradycardia and incidence of cardiac anomalies in deep-diving marine mammals." *Nat Commun*, Vol. 6, article 6055, January 16, 2015. doi:10.1038/ncomms7055.
4. Bickett, N.; Tift, M.; St. Leger, J. and Ponganis, P. "Heart Rate Regulation in the Killer Whale." *FASEB J*, Vol. 30, April 1, 2016, pp. 1230.9-1230.9. [https://faseb.onlinelibrary.wiley.com/doi/abs/10.1096/fasebj.30.1\\_supplement.1230.9](https://faseb.onlinelibrary.wiley.com/doi/abs/10.1096/fasebj.30.1_supplement.1230.9)
5. Elmegaard, S.L.; Johnson, M., Madsen, P.T. and McDonald, B.I. "Cognitive control of heart rate in diving harbor porpoises." *Curr Biol*, Vol. 26, November 21, 2016, pp. R1175-R1176. doi: 10.1016/j.cub.2016.10.020.
6. Goldbogen, J.A.; Cade, D.E.; Calambokidis, J.; Czapanskiy, M.F.; Fahlbusch, J.; Friedlaender, A.S. et al. "Extreme bradycardia and tachycardia in the world's largest animal." *PNAS*, Vol. 116, December 10, 2016, pp. 25329-25. doi:10.1073/pnas.1914273116.

KEYWORDS: Marine Mammal Health; Dolphin; Mobile Electrocardiogram Monitor; Wearable Heart Rate Monitor; ECG; Heart Rate; Heart Rhythm; Cardiac Disease



# VERSION 5

N212-126 TITLE: GHz Optical Underwater Detection Receiver

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Sensors; Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop a wide bandwidth (GHz), multi-element optical receiver to enable the extraction of both reflectivity and range features of objects in water. The optical receiver should have high sensitivity at visible wavelengths and sufficient dynamic range to detect signals in high clutter environments.

**DESCRIPTION:** Time resolved detection is needed in underwater imaging to distinguish between desired object returns and unwanted environmental clutter. Sufficient resolution ( $< 5\text{cm}$ ) in both space and time is required to identify underwater threats. While techniques have been developed on the transmitter side to create high bandwidth optical interrogation signals, the receiver side has been limited to single element receivers that must be mechanically scanned to image a scene. Such a configuration is not compatible with moving platforms. While time of flight cameras have been developed for the automotive industry, these cameras do not have the time resolution necessary to operate in high clutter environments. A multi-element, wide bandwidth optical receiver is needed to achieve the benefits of high time resolution with a spatially resolved optical detector.

**PHASE I:** Develop a concept for a multi-element ( $>10,000$ ), wide bandwidth (1GHz) optical receiver with optical sensitivity in the blue-green wavelengths. The concept should include methods to simultaneously sample the optical receiver elements with sufficient speed to enable the processing of GHz-bandwidth signals. Areas of technical risk and mitigation methods should be identified. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Design, build and test the multi-element, wide bandwidth optical receiver developed in Phase I. Test the developed optical receiver with wide bandwidth, chirp-modulated optical signals to verify its capability to recover high bandwidth signals with multiple receiver elements.

**PHASE III DUAL USE APPLICATIONS:** Support the Government in transitioning the optical receiver to fielded laser imaging systems. Dual use opportunities include unmanned underwater vehicle (UUV) surveying and automotive light detection and ranging (LIDAR).

## REFERENCES:

1. Mullen, L.; Lee, R. and Nash, J. "Digital passband processing of wideband-modulated optical signals for enhanced underwater imaging." *Applied Optics*, vol. 55, no. 31, 2016, pp. C18-C24.
2. Mack, K.V.; Jemison, W.D.; Rumbaugh, L.K.; Illig, D.W. and Banavar, M.K. "Time-of-Flight (ToF) Cameras for Underwater Situational Awareness." *Proceedings of OCEANS 2019 MTS/IEEE Seattle*, 2019, pp. 1-5.



## VERSION 5

3. Kadambi, A.; Schiel, J. and Rasker, R. “Macroscopic Interferometry: Rethinking Depth Estimation with Frequency-Domain Time-of-Flight.” Proceedings of 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR), Las Vegas, 2016.

KEYWORDS: LIDAR; laser imaging; underwater vision; time of flight camera; 3D camera; modulated laser; undersea weapon; underwater sensor

# VERSION 5

N212-127      TITLE: High-Temperature Fuel Coking Mitigation Frangible Coatings for Fuel Nozzles and Screens

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR);Hypersonics

TECHNOLOGY AREA(S): Air Platforms;Materials / Processes

OBJECTIVE: Develop a frangible coating that can slough off carbonaceous deposit precursors adhering and growing onto fuel-wetted surfaces, such as “last-chance screens”, to prevent dysfunction of critical aircraft fuel system components.

DESCRIPTION: Increasing heat loads, projected today for advanced aircraft of the near future, will lead to higher average fuel system temperatures for both commercial and military aircraft [Ref 1]. However, fuel deposit issues currently prevent long-term fuel system operation at temperatures over ~300F [Refs 2, 3]. Fuel deposit issues are also projected to increase in current generation aircraft: for example, a recent analysis of F-24 fuel obtained from a military garrison showed extreme thermal stability problems – high coke deposition in fuel lines and hysteresis on critical valves – indicating a potential increase in thermal stability issues following the transition from JP-8 to F-24 [Ref 4]. Special consideration for Navy fuels, JP-5 with copper contamination should be made.

While the formation of carbonaceous deposits can be problematic for several components of an aircraft fuel system, it is expected to have the highest negative impact in the vicinity of the fuel injectors, which are wetted by fuel with the highest time-at-temperature exposure. Of some concern are the “last-chance screens”, positioned immediately upstream of the fuel injectors, because the screen openings comprise some of the smallest fuel passages in the entire system and are exposed to fuel of temperature sufficient for coke formation. Blockage of these passages can have serious consequences in terms of aircraft propulsion control.

A thin, conformal coating applied directly onto the screen would be a direct and cost-effective mitigation approach for deposit prevention; moreover, it would incur no weight penalty. However, the highly reactive radicals implicated in jet fuel deposition phenomena [Ref 5] are known to attach indiscriminately to essentially any organic or inorganic surface. For that reason, typical off-the-shelf “release coatings” are not a very effective mitigation approach even though some are better than others. The objective of the proposed SBIR topic is to create a frangible coating that can slough off carbonaceous deposit precursors adhering and growing onto fuel-wetted surfaces, thus preventing blockage on the most critical, most susceptible aircraft fuel system components. The thickness of the coating and its erosion rate should be adjusted such that it can remain operational for a time frame comparable to a typical fighter aircraft engine service interval, targeting a 5X increase in Mean-time Between Overhaul (MTBO) compared to the baseline at 400F fuel operation.

## KEY FRANGIBLE COATING ATTRIBUTES

- “Frangibility”: Low cohesive strength of nano-layers prevents build-up by shedding adhered varnish precursors.
- Nano-scale, conformal coating for complex geometries applied via vapor deposition.
- Lubricity equal to or higher than underlying material, coefficient of friction equal to or lower than underlying metal, chemical inertness.
- Temperature stability up to 600F.
- Nano- to micro-meter coating thickness.
- No off-gassing or other contamination.

## VERSION 5

PHASE I: Focus on vapor deposition parameter optimization onto bill-of-materials last-chance screen samples. Confirm spectroscopically that a uniform, defect-free coating of thickness not-to-exceed 1  $\mu\text{m}$  can be applied on a 200 to 120  $\mu\text{m}$  mesh wire stainless steel screen such that it covers the entire surface (front and back) leaving no areas of exposed metal.

PHASE II: During this phase, candidate samples resulting from the optimization efforts in Phase I will be tested with 400F flowing fuel under nominal cruise conditions and/or other conditions characterized by low fuel flow at high temperature. Evaluate within a long-duration test rig constructed with design parameters such that it simulates, as faithfully as possible, fuel system flow conditions and geometries expected in a real aircraft fuel system, with emphasis on time-at-temperature of the fuel entering the screen. The samples will be tested vis-à-vis a control (uncoated) wire mesh screen. Update vapor deposition application conditions and coating thickness based on evaluation of the flowing fuel test results in an iterative fashion until the coating application conditions which lead to the most successful coating validated under real aircraft fuel system flow conditions are identified. Demonstrate a coated screen exposed to flowing 400°F JP-5 fuel that exhibits a 5X increase in the run time to reach 80% blockage compared to a control (uncoated) screen.

PHASE III DUAL USE APPLICATIONS: Focus on the development of manufacturing methods to improve component yield, production time, and component cost. Determine whether fuel system and components with the new screens require requalification or whether the screens can be qualified independently. Identify opportunities to use the technology in manufacturing areas, such as semiconductor fabrication and additive manufacturing, to prevent fouling of small and intricate tooling.

### REFERENCES:

1. Dahm, Werner J. A. et al. "United States Air Force Scientific Advisory Board Report on Thermal Management Technology Solutions, Vol. 2, SAB-TR-07-05-NP, August 2007. <https://www.scientificadvisoryboard.af.mil/Studies/>.
2. Hazlett, R. N. "Thermal Oxidation Stability of Aviation Turbine Fuels." ASTM, Philadelphia, January 1, 1991. <https://www.osti.gov/biblio/5157176-thermal-oxidation-stability-aviation-turbine-fuels>.
3. Zabarnick, S. "Studies of Jet Fuel Thermal Stability and Oxidation Using a Quartz Crystal Microbalance and Pressure Measurements," Ind. Eng. Chem. Res. , 33, May 1, 1994, pp. 1348-1354. <https://pubs.acs.org/doi/pdf/10.1021/ie00029a034>.
4. Morris, Robert W., Jr.; Shardo, James R.; Marcum, Grady; Lewis, William K.; Wrzesinski, Paul J. and Bunker, Christopher E. "AFRL-RQ-WP-TR-2018-0019: Characterization of an On-spec, Commercial Grade, Jet A and a Near-off-spec Military F-24 (Final Report)." Air Force Research Laboratory, Aerospace Systems Directorate, January 2018. <https://apps.dtic.mil/sti/pdfs/AD1049235.pdf>.
5. Sander, Z. H. et al, "Experimental and Modeling Studies of Heat Transfer, Fluid Dynamics, and Autoxidation Chemistry in the Jet Fuel Thermal Oxidation Tester (JFTOT)." Energy Fuels 2015, 29, 11, pp. 7036-7047. <https://pubs.acs.org/doi/pdf/10.1021/acs.energyfuels.5b01679>.

KEYWORDS: coating, frangible, jet fuel, fuel nozzle, last chance screen, vapor deposition, carbonaceous deposit precursors

# VERSION 5

N212-128      TITLE: Publicly Available Information Analysis Curation Tool

RT&L FOCUS AREA(S): Autonomy;Networked C3

TECHNOLOGY AREA(S): Battlespace Environments;Human Systems;Information Systems

OBJECTIVE: Develop a cloud-based tool set to facilitate the creation of an analyst's notebook or journal to catalog and document the analysis of publicly available information.

DESCRIPTION: Information environment analysts use multiple tools to track information environment threats, narratives, propaganda, and their own communication efforts and impacts. Analysts have no means of recording their investigations through the steps they take to come to a logical conclusion or record their suppositions about activities, intentions, and proclivities of information actors or the streams of information from topic communities using common hashtags, suspected botnets and coordinated actors, and the information maneuvers in play that relate to commander's intent. The use of multiple tools is necessary. Current methods are labor intensive and lack the capabilities for tagging, searching and supporting analysis or for providing an archive of analyses useful for tracking change over time. The envisioned capability will enable analysts to create journals of their analyses, enabling them to investigate phenomena in Publically Available Information (PAI) over time; develop better information products and reports; and track performance and effectiveness of operations in the information environment. The capability will facilitate screen shots from web-based sources and analytic tools, with additional capabilities for annotation, search, and tracking of activities and events in the digital information environment so that analysts and decision makers can develop tailored, mission playbooks to enable planning and evaluation of performance and effectiveness over time.

The result would be the development of an electronic, searchable “analyst’s journal.” Currently, record keeping by analysts is piecemeal, documented only as final work products such as reports in Word or PowerPoint for presentation. This capability will streamline work flow for faster analyses, better “look back” ability to see how an information threat behaves over time, and the capability to visualize and understand correlation and causality regarding activities on social and digital media platforms. The “analyst’s journal” will provide a substantial improvement over existing Tactics, Techniques, and Procedures (TTPs) in social media analysis. The various services have strong demand for the development of social media playbooks that are tailored to the demands and concerns of particular missions. This effort will provide the means for developing a playbook, allowing analysts and decision makers to track metrics of effectiveness and metrics of performance, emerging information environment threats, and blue as well as red activities on social media.

PHASE I: Design and develop a cloud-based tool set for capturing and cataloging screen shots with some semi-automated tagging capabilities and a task-oriented editor for tracking information maneuvers, threat actors and influencers, and analyst’s research across multiple platforms and tools to enable the creation of an electronic, searchable and archivable “analyst’s notebook” with a user-friendly interface.

PHASE II: Develop the working prototype of the data curation toolset that can work across multiple tools and incorporate screen shots of relevant websites and other Internet assets. Enable the development of smart-tagging and the curation of multiple analyst notebooks into a “watchstander’s notebook” to aggregate the work of more than one analyst, with templates for different types of analysts such as public affairs, information operations, and Military Information Support Operations. Expand the capabilities of the analyst’s and watchstander’s notebooks to a full, tailored playbook for operations in digital and social media, to support decision maker’s needs at the middle and upper tiers of operational authority. Create capabilities for planning and assessment of operations on the digital and social media platforms.

## VERSION 5

PHASE III DUAL USE APPLICATIONS: Many marketing and brand name companies employ analysts to investigate the effectiveness of their advertising. With the high growth of existing platforms and the expansion of the number of important, relevant platforms, one tool for analysis is no longer sufficient for understanding activities and events relevant to their companies and their customers. Brands and marketing firms also must deal with new problems: trolling, meme conflicts and smear campaigns need to be discovered, tracked and countered. Currently, their analysts lack an integrated system for managing multiple tools and their investigations into what's happening on multiple platforms. As the market for these new tools grows at a steady, high pace, the need for a system to easily and simply track an analyst's research is expected to grow.

### REFERENCES:

1. Beskow, D. and Carley, K. "Social Cyber Security: An Emerging National Security Requirement." *Military Review*, Volume 99(2), March-April 2019, pp. 117-127.
2. Carley, K. "BEND: A Framework for Social Cyber-Security." *Future Force Magazine*, Navy Science and Technology. Vol 6., Number 2, 2020, pp. 22-27. <https://futureforce.navylive.dodlive.mil/issues/>.
3. Beskow, D. and Carley, K. "Investing in Social Cybersecurity" *Future Force Magazine*, Navy Science and Technology. Vol 6., Number 2, 2020, pp. 16-21. <https://futureforce.navylive.dodlive.mil/issues/>.

KEYWORDS: Social Media Analytics, Public Affairs, Information Environment Assessment, Information Warfare, Analysis, Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance, C4ISR

# VERSION 5

N212-129 TITLE: Components for a Deep Operating Unmanned Underwater Vehicle

RT&L FOCUS AREA(S): Microelectronics;Networked C3

TECHNOLOGY AREA(S): Battlespace Environments;Electronics;Ground / Sea Vehicles

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop and demonstrate pressure tolerant deep Unmanned Underwater Vehicle (UUV) components such as flooded motors, pressure tolerant electronics, and communication systems that work at ocean depth with the goal of improved performance, stealth, and reduced Size Weight and Power (SWaP).

**DESCRIPTION:** The U.S. Navy wishes to extend applications of UUVs to missions that require operation at greater depths, speeds, endurance, and stealth. Some future missions will be conducted using larger UUVs (Large Displacement Underwater Unmanned Vehicles [LDUUVs] aka Snakehead and Extra Large Unmanned Underwater Vehicles [XLUUVs]) than are currently common but must remain affordable. The motor drive the majority of the cost for these systems and currently cost \$1M Future missions will require operation to the abysmal depths of 5 km. or more. Future missions will require average speeds of 6-7 knots (kts.) and endurance on the order of days to weeks. Some future missions will require stealth at speed. Means of communicating while remaining at depth will be required. Current missions often use smaller (Small Diameter UUV (SDUUVs) and Medium Diameter UUVs (MDUUVs)) relatively affordable UUVs operating at lower speeds (3-4 knots) for shorter duration (one a day) on the continental shelf. Stealth has been a requirement but it is easier to achieve low speed. Hence new propulsion systems and signature quieting systems are sought for deep operating UUVs. The plan is to feed successful SBIR efforts into a Tech Candidate executing over FY22 to FY23 leading to and Future Naval Capability (FNC) executing over FY24 to FY25.

Typical communication solutions for submerged, deep operating, UUVs are limited. The Navy is seeking novel solutions for both unidirectional and bidirectional communications for Command and Control of the deep diving UUVs.

Electronics in Deep Diving UUVs have the option to either be pressure tolerant or protected within a pressure vessel to protect against the immense forces of the deep ocean. Commercial Off-the-Shelf (COTS) electronics can be kept at atmospheric pressure with minimal modifications as long as a pressure vessel (PV) is utilized. However, the PV adds cost, size and weight to the electronic housing as well as requiring expensive, long-lead connectors to and from the PV. An alternative is to have pressure tolerant electronics (PTE) designed to operate in nonconductive-fluid-filled enclosures at the ambient ocean pressure. While there are several existing PTE solutions, these are often one-off designs. Deep UUV may have need for a variety of sensors such as side scan sonar, magnetic, LiDAR, and optical to perform their mission. Any deep operating UUV would greatly benefit from not requiring a PV around these sensors.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved

## VERSION 5

by the Defense Counterintelligence and Security Agency (DCSA) formerly Defense Security Service (DSS). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances. This will allow contractor personnel to perform on advanced phases of this project as set forth by DCSA and ONR in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Perform a feasibility study for novel deep UUV components for potential inclusion on next generation deep operating UUVs. These components can include conceptual design and CONOPS of new propulsion system, new communication system and links for deep UUVs, and/or modification of sensors to allow them to not require PVs by implementing PTEs for performance up to full ocean depth.

PHASE II: Develop and test a prototype for the proposed approach. This shall include hydrostatic testing of the components. Complete preliminary performance testing in a surrogate environment.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Extensively test the prototype fabricated in Phase II and examine mission performance under nominal operating conditions and well as performance in suboptimal environments and conditions.

Potential dual use applications include deep water resource mining and oil/gas extraction.

### REFERENCES:

1. Moreels, Daan and Leijnen, Peter. "Turning the electric motor inside out: A Belgian startup's axial-flux motor for EVs is small, light, and powerful. " IEE Spectrum, Oct 2019.
2. Barnes, H. E. and Gennari, J. J. "A Review of Pressure Tolerant Electronics (PTE)." US Department of Commerce, NTIS, AD-AO27 907.
3. Kampmann, P.; Lemburg, J.; Hanff, H. and Kirchner, F. "Hybrid pressure-tolerant electronics." Oceans 2012 MTS/IEEE Hampton Roads Conference & Exhibition, October 2012, pp. 1-5.

KEYWORDS: Axial Flux Motor; Pressure Tolerant Electronics; Underwater-to-Air bistatic/monostatic communication; UUV; LDUUV



# VERSION 5

N212-130      TITLE: Integrated Sensor Technologies for Composites

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Materials / Processes;Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop integrated sensor technologies that can be incorporated into composite primary structures to allow for the monitoring and characterization of the structures' behavior to support their development, production, and sustainment.

**DESCRIPTION:** Composites materials are used extensively throughout the aerospace industry due to their great specific strength and stiffness. Unlike traditional metallic components, the ultimate performance of composites can be much harder to characterize and monitor because they are a product of the manufacturing process, can be susceptible to aging issues, and damage may be difficult to identify. Traditionally strain gages are used to characterize a structure and can only sense a very limited portion of that structure, are labor intensive to install, and can be susceptible to handling damage. Traditional strain gages and the associated wiring are generally only used for limited test activities and were not intended for prolonged monitoring and for durability over the deployment of the system. Embedded sensors would allow the structural integrity and behavior of composite structures to be effectively monitored to address the previously described challenges throughout the entire product lifecycle. This will help improve the depth of understanding of these products and assist in driving down lifecycle costs, particularly in the area of sustainment. This sensing system should be designed to operate within the environmental constraints that would be expected of aerospace composites and should be mindful of size and weight to minimize their impact to the flight vehicle while balancing the performance of the sensor.

The sensor system should consider the following parameters:

- Capable of taking distributed measurements over a length or area
  - Max Span: ~10 ft
  - Measurement distribution: ~inches
- Measuring one or more of the following, ranges shown are indicative of a representative order of magnitude:
  - Strain (microstrain, inches, 0-5%)
  - Displacement (0"-0.1")
  - Impact detection/impact damage detection
  - Delamination
  - Force (0-10000's lbs)
  - Temperature (32F-500F)
- Modular interface with different data logging equipment
  - Enable interfacing with lab console, remote data storage, or to a communication system for real time transmission

## VERSION 5

- Note that remote data storage would be removed before flight and would not need to survive flight loads
- Service life of greater than 25 years.
  - Can be powered by either an internal or external power source.
  - System size and weight should consider that some elements may be integrated with a flight system and will need to be minimized as much as practical.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Define and develop inspection and sensor concepts and assess their feasibility. Examine concept formulation, development, and possible validation that could include subscale demonstration, including data logging operations. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II. Prepare a Phase II plan.

PHASE II: Develop and validate a prototype (not necessarily hardware). Solidify the process for designing and incorporating the sensors into a variety of structures, such as primary aerospace vehicle structures of complex geometry, specific detail will be provided after award. The cost to procure and implement the system should be assessed. Quantify the performance of the embedded sensor, corresponding data logging equipment, and the sensor's impact on the system.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Work with the Navy to formalize the process for the final design, integration, calibration and/or correlation of the integrated sensors for use to help with the detection of the early failure of parts, which will aid in the reliability of systems and mutually benefits the Navy and aerospace industry. This will include the qualification of the sensing system for use on Navy and aerospace primary and secondary structures.

### REFERENCES:

1. Measures, R. "Smart Composite structures with embedded sensors." Composites Engineering, Volume 2, Issues 5-7, 1992. <https://www.sciencedirect.com/science/article/pii/0961952692900458>.
2. Murukeshan, V., Chan, P., Seng, O. and Asundi, A. "On-line health monitoring of smart composite structures using fiber polarimetric sensor." Smart Materials and Structures, Volume 8, Number 5, 1999. <https://iopscience.iop.org/article/10.1088/0964-1726/8/5/303>.
3. Kelly, A., Davidson, R. and Uchino, K. "5.20-Smart Composite Materials Systems." Comprehensive Composite Materials, Volume 5, 2000. <https://www.sciencedirect.com/science/article/pii/B0080429939009992>.
4. Schaaf, Kristin Leigh. "Composite materials with integrated embedded sensing." UC San Diego Electronics Theses and Dissertations. <https://escholarship.org/uc/item/0gx2j946>.
5. Rathod, Vivek and Deng, Yiming. "Structural compatibility of thin film sensors embedded in a composite laminate." Proc. SPIE 1096728, 2019. <https://www.spiedigitallibrary.org/conference->

## VERSION 5

[proceedings-of-spice/10967/1096728/Structural-compatibility-of-thin-film-sensors-embedded-in-a-composite/10.1117/12.2514393.short?SSO=1](https://proceedings-of-spice/10967/1096728/Structural-compatibility-of-thin-film-sensors-embedded-in-a-composite/10.1117/12.2514393.short?SSO=1).

KEYWORDS: Strategic Missiles; Composite Materials; Health Monitoring; Embedded Sensors; Optical Strain Gauge; Damage Detection

## VERSION 5

N212-131 TITLE: Innovative Manufacturing/Materials for Structural Insulators in Hypersonic Flight Body Thermal Protection Systems

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR);Hypersonics;Space

TECHNOLOGY AREA(S): Battlespace Environments;Materials / Processes;Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop low conductivity thermal insulation materials comparable to current generation commercial products that provide higher levels of strength at temperature and are manufactured by Aerospace-grade methods/processes as befits the Navy application. Current methods are basically Industrial grade.

DESCRIPTION: The best performing commercial insulation products are oxide-based felts and blankets produced in bulk for furnace linings and furnace furniture. They are well known and have been available for many decades. While low in cost and providing excellent thermal resistance, they are not typically intended for structural load bearing applications. The bulk manufacturing process tends to add local property variations, which are not always averaged out in the finished component form factor. Furthermore, the bulk format of these materials adds additional steps to the flight vehicle assembly as vehicle piece parts are fabricated from the bulk materials. Availability in near-net shape format would remove this secondary fabrication step and simplify vehicle assembly.

Thus, the opportunity presented by this SBIR topic is to apply some of the advanced aerospace composite materials and manufacturing technology developed over recent years; including but not limited to: fiber reinforcement, fiber coatings, tape placement, tape wrapping, 3D weaving, additive manufacture to develop reliable, uniform, low thermal conductivity/high strength materials and near-net shape components in form-factors applicable to Navy hypersonic flight vehicles.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Demonstrate low thermal conductivity and structural capability of materials/manufacturing solutions at the desk top/lab scale level. Figures of merit for comparison against current commercial products are physical density less than 0.7 g/cm<sup>3</sup>, compressive strength greater than 750 psi, melting point greater than 3400°F, and in-plane/through thickness thermal conductivity less than 0.4 W/mK up to 3000°F against a commercial benchmark are the figures of merit [Ref 1]. Both active (decomposing) and passive

## VERSION 5

insulation approaches are acceptable. Active approaches must still show equivalent weight performance improvement over benchmark materials as well as a discussion of strength retention and decomposition product management in a flight vehicle environment. Active approaches should also be able to function over a mission time of one hour. Current commercial products are available in blanket and plate format [Ref 2]. Companies should also discuss manufacturing approach and scale-up potential for production of aerospace grade hardware.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Produce prototype hardware to the requirements, materials, form factors and manufacturing approach from Phase I. Material thermal and mechanical characterization data will also be provided in order to assess replacement risk against current incumbent materials. At the end of Phase II, prototype hardware will be provided for government evaluation in a simulated flight test environment.

It is probable that the work under this effort will be classified under Phase II. See details in the Description.

PHASE III DUAL USE APPLICATIONS: In Phase III the firm will be expected to work with the government to integrate the final phase II product into Navy systems. Additional testing, such as flight tests, will occur then. High temperature capable, low thermal conductivity materials and components would have much interest in the commercial access-to-space environment, commercial aerospace, and gas turbine engine applications.

### REFERENCES:

1. Soboyejo, W. O.; Obayemi, J. D. and Annan, E. "Review of High Temperature Ceramics for Aerospace Applications." Advanced Materials Research, 2015, pp. 385-407. [https://www.researchgate.net/publication/287972274\\_Review\\_of\\_High\\_Temperature\\_Ceramics\\_for\\_Aerospace\\_Applications](https://www.researchgate.net/publication/287972274_Review_of_High_Temperature_Ceramics_for_Aerospace_Applications).
2. "OEM Insulation: Aerospace." Johns Manville, 2020. <https://www.jm.com/en/oem/aerospace/>.

KEYWORDS: Conventional Prompt Strike; Thermal Protection System; Structural Insulators; High Thermal Diffusivity Materials; Thermal Resistance; Reentry Vehicles; Hypersonic Vehicle Heat Loads

# VERSION 5

N212-132 TITLE: Large Footprint Silicon Leadless Chip Carrier (LCC)

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Electronics;Materials / Processes;Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop a large footprint (~2 cm x 2 cm) silicon Leadless Chip Carrier (LCC) that is strategically radiation-hardened for use with Micro-Electromechanical-System (MEMS) sensors.

**DESCRIPTION:** The performance requirements for sensors used in strategic navigation applications continue to be stringent, necessitating continued innovation for sensor packaging technologies. For commercial applications, conventional LCC materials are typically acceptable for most silicon MEMS sensors, but for strategic applications, the stress induced from coefficient of thermal expansion (CTE) creates mismatches between the package and the sensor, which can result in significant performance errors. Additionally, the radiation-hardness required for strategic applications disqualifies many conventional silicon chip packages from being considered. Examples of existing research for LCC for use with MEMS sensors can be found in the referenced articles [Refs 1-5].

A silicon LCC that can meet the stringent performance requirements of strategic instrumentation is likely to bring value to many existing commercial applications, to support packaging of high performance MEMS which can be used across the commercial class use, for example in automotive class accelerometers among many others.

**PHASE I:** Design a manufacturing process using existing capabilities in the market to produce a package with the desired goals of: 1) having 40 or more pins that are isolated from an electrically conductive substrate; 2) accommodating chips that have the approximate dimensions: 17mm x 17mm x 3mm; and 3) incorporating a hermetic seal ring to be used with a silicon cap. Material space is not constrained and unique designs are encouraged. Analyze all aspects of fabrication to assess and justify the feasibility and practicality of the designed approach. If the Phase I Option is exercised, include the initial design specifications and capabilities description to build prototype solutions in Phase II.

**PHASE II:** Based on the Phase I design and execution plan, fabricate and characterize a small lot (up to Qty: 3) of prototype packages. Characterization shall comprise various parameters, including continuity/isolation of the pins, hermeticity of the package, and mechanical surface features (e.g., flatness, parallelism, heights). Deliver the prototypes by the end of Phase II.

**PHASE III DUAL USE APPLICATIONS:** Based on the prototypes developed in Phase II, continuing development must lead to productization of silicon LCCs. While this technology is aimed at military/strategic applications, LCCs are heavily used in numerous other applications. A silicon LCC that can meet the stringent performance requirements of strategic instrumentation is likely to bring value to many existing commercial applications to support packaging of high performance MEMS, which can be used across the commercial class use for example in automotive class accelerometers.

# VERSION 5

## REFERENCES:

1. Lee, K. et al., United States Patent: 3D Interconnect Structure Comprising Through-Silicon Vias Combined with Fine Pitch Backside Metal Redistribution Lines Fabricated Using a Dual Dasmascene Type Approach.” US 9,530,740 B2. <http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetacgi%2Fsearch-bool.html&r=1&f=G&l=50&col=AND&d=PTXT&s1=9530740&OS=9530740&RS=9530740>.
2. Edelstein, Daniel et al. “Silicon Chip Carrier with Conductive Through-Vias and Method for Fabricating Same.” US 2006/0027934 A1. <https://patents.google.com/patent/US20060027934A1/en>.
3. Zhao, Y. “Chip-Scale Package for Integrated Circuits.” US 2006/0216857 A1. <https://www.freepatentsonline.com/y2006/0216857.html>.
4. MA, Qing et al. “Interposer For Hermetic Sealing of Sensor Chips and For Their Integration with Integrated Circuit Chips.”, US 2016/0280539 A1. <https://www.freepatentsonline.com/y2016/0280539.html>.
5. Hilton, A. and Temple, D. “Wafer-Level Vacuum Packaging of Smart Sensors.” Sensors, 16(11), 2016, p. 1819. <https://pubmed.ncbi.nlm.nih.gov/27809249/>.

KEYWORDS: Micro-Electromechanical-System; MEMS; Packaging; Leadless Chip Carrier; Navigation; Sensors; radiation-hardened



# VERSION 5

N212-133 TITLE: Microfabricated Noble Gas Vacuum Pump

RT&L FOCUS AREA(S): Quantum Science

TECHNOLOGY AREA(S): Electronics;Materials / Processes;Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop a method for pumping noble gases at ultra-high vacuum ( $1\text{e-}7$  to  $1\text{e-}10$  Torr) that is compatible with microfabricated atomic vapor cells and can either be able to be fabricated simultaneously with a silicon-based vacuum cavity or be bonded to, inserted in, or otherwise attached to a silicon-based vacuum cavity.

**DESCRIPTION:** Atomic inertial sensors and clocks often require high or ultra-high vacuum to operate. While non-evaporable getters can provide high pumping rates for many gases, they cannot capture noble gases. As a consequence, helium and to a lesser extent argon can leak through glass windows, ultimately raising the pressure inside the vacuum cavity to unworkable levels. In laboratory scale systems, those noble gases are typically pumped out by ion pumps. While progress has been made to reduce the size of the atomic vacuum cavity [Refs 1-3], even the smallest commercial ion pumps are relatively bulky in comparison ( $\sim 500\text{ cm}^3$  compared to  $< 1\text{ cm}^3$ ). Thus far, microfabricated atomic systems have either operated at higher pressures with a buffer gas, or have relied on slowing the leakage of helium from a careful selection of window material. An active noble gas pump would be a distinct advantage in creating compact, long-lifetime, ultra-high vacuum cavities.

A number of commercial sensors (e.g., accelerometers, pressure sensors, microbolometers) require an evacuated chamber to meet their performance goals. Improved vacuum conditions may be able to extend the useful lifetime of these devices, but would be critical for the performance of ultra-precise inertial sensors and clocks that are particularly useful to military programs. There exist multiple avenues for innovative solutions to this problem (e.g., development of novel microstructured materials to aid in the miniaturization of ion pumps), hence the desire for an SBIR effort.

Significant advances have been made to create ever-small vacuum pumps [Refs 3,4], but there does not yet exist a solution that satisfies the combination of fabrication method and pumping performance required for atomic systems. The applications for such a pump extend beyond atomic systems; any system that needs to operate at even modest vacuum (e.g., mTorr) with a glass component will ultimately be lifetime-limited by the leak rate of helium so could benefit from an improved vacuum pump.

**PHASE I:** Perform a design and materials study to assess the feasibility of fabricating an ultra-compact vacuum pump capable of pumping noble gases at ultra-high vacuum ( $1\text{e-}7$  to  $1\text{e-}10$  Torr). The study shall analyze potential approaches, exploring the risks and risk mitigation strategies associated with each, and identify the most promising option. Similarly, the study shall detail the planned fabrication process, again identifying risks and risk mitigation strategies. The study shall include an evaluation of the anticipated (goal) size ( $< 20\text{ cm}^3$ ), electrical power draw ( $< 1\text{ W}$ ), robustness, and lifetime ( $> 2\text{ yr}$  at  $10\text{-}9$  Torr) of the final device. Finally, the study should discuss how the pump can be combined with a silicon-based vacuum

## VERSION 5

cavity. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build prototype solutions in Phase II.

PHASE II: Fabricate and test a small lot (up to Qty of 3) of the device designed in Phase I. Ensure that the prototypes are prepared in such a way that they can be bonded to a cavity and prepared for third party testing. Characterization of the components shall be performed, demonstrating their basic performance (e.g., noble gas pump speed, lowest achievable pressure) and evaluating their heat production, magnetic character, and robustness to vibration. Deliver the prototypes by the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Advancement of microfabricated noble gas pump technology has applications in any field that requires a long-lasting vacuum, e.g., MEMS vibration or acceleration sensors, pressure sensors, gas sensing microsystems, etc. For use in laboratory applications in chemical and biological testing.

### REFERENCES:

1. Kitching, John. "Chip-scale atomic devices". Applied Physics Reviews 5, 031302, (2018). DOI: 10.1063/1.5026238. <https://aip.scitation.org/doi/10.1063/1.5026238>.
2. Knapkiewicz, Pawel. "Technological Assessment of MEMS Alkali Vapor Cells for Atomic References." Micromachines 2019, 10(1), 25. DOI: 10.3390/mi10010025. <https://www.mdpi.com/2072-666X/10/1/25/html>.
3. Knapkiewicz, Pawel. "Alkali Vapor MEMS Cells Technology toward High-Vacuum Self-Pumping MEMS Cell for Atomic Spectroscopy." Micromachines 2018, 9(8), 405. DOI: 10.3390/mi9080405. <https://www.mdpi.com/2072-666X/9/8/405>.
4. Grzebyk, Tomasz. "MEMS Vacuum Pumps." Journal of Microelectromechanical Systems, Vol. 26, Issue4, August 2017. DOI: 10.1109/JMEMS.2017.2676820. <https://ieeexplore.ieee.org/document/7888534>.

KEYWORDS: atomic sensor; atomic clock; inertial sensor; vacuum; microfabrication; Micro-Electromechanical-System; MEMS, pump

# VERSION 5

N212-134 TITLE: Moderate Spectral Resolution Spectrometer

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Electronics;Materials / Processes;Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop and demonstrate a Moderate Spectral Resolution Spectrometer that can be deployed on telescopes currently in use or being considered for future use by the United States Naval Observatory (USNO) to collect data. The spectrometer will have a moderate resolution ( $R \sim 500$ ), be capable of observing wavelengths in the range of 0.5-1.6 micrometer, and be able to be deployed on moderate-aperture ( $D = 20\text{-}40$  cm) telescopes.

**DESCRIPTION:** Currently, USNO collects photometric data, including bright star spectra, which is converted into artificial stellar spectra. This photometric data must be measured and monitored periodically to ensure weapon system utility and performance. The data measured by USNO at present contains gaps that inhibit a comprehensive formulation of stellar spectra. A Moderate Spectral Resolution Spectrometer would enable the tailoring of data collection through direct monitoring of spectral ranges of interest to the Navy, thereby reducing both costs and scheduling impacts, and increasing reliability and accuracy of current and future star catalogs within the FC subsystem. Such an instrument would be useful to the larger DoD community, the United States Geological Survey (USGS), astronomical situational awareness communities, and commercial providers of such data; thus, the commercialization potential for this spectrometer is assessed to be high. All work executed under this topic will be unclassified.

**PHASE I:** Develop and define a concept design for a Moderate Resolution Spectrometer that can be deployed to moderate aperture-class ( $D = 20\text{-}40$  cm) Navy telescopes. The deployed spectrometer will be used to collect the stellar data needed by the Navy. Work with the Navy in understanding size, function, and interface requirements for the spectrometer. Construct measures that ensure data and network connection integrity and USNO software application.

Specific threshold requirements/goals are as follows:

- Fiber-fed: Threshold, spectral range -  $\lambda$ : 800-1000 nm
- Goal, spectral range -  $\lambda$ : 500-1600 nm
- Spectral resolution,  $R$ : Threshold - 200-500 ( $R = \lambda / \Delta \lambda$ )
- Goal, functionality: switchable between “modes”:
- Goal, mode 1: 1000-2000
- Goal, mode 2: 5000-20000

Identify risks to the proposed concept and develop Phase II plans that include ways to mitigate those risks for Phase II. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

## VERSION 5

PHASE II: Produce and deliver a prototype Moderate Resolution Spectrometer. Work with the Navy to fully understand the data and interface requirements and to understand hardware and integration standards to be deployed with moderate aperture-class ( $D = 20\text{-}40$  cm) telescopes currently used by the USNO. Provide testing scenarios that ensure Navy operational use with the telescope designed to show data collection efficiencies compared to current practice. Establish a feedback loop with the Navy for implementing changes due to prototype testing. All the work under this Phase II effort will be unclassified.

PHASE III DUAL USE APPLICATIONS: Deliver a Moderate Resolution Spectrometer for telescopes deployed by USNO in a manner that fulfills bright star photometric data requirements and are usable by NSWCCD FC capabilities. Provide design and test cases that demonstrate integration of the spectrometer in photometric data collections. Support remote field qualification testing with a spectrometer deployed on off-site telescopes. Work with the Navy to set up a Moderate Resolution Spectrometer with deployed telescopes to include troubleshooting and resolving implementation/execution issues at various Navy, DoD, and civilian telescope observatories.

### REFERENCES:

1. Bohlin, R. C., Gordon, K. D., and Tremblay, P. "Perfecting the Photometric Calibration of the ACS CCD Cameras." E. 2014, PASP, 126, 711. <https://arxiv.org/pdf/1606.01838.pdf>.
2. Han, W.; Mack, P.; Lee, C.-U. et al., "Development of a 1-m Robotic Telescope System." Publications of the Astronomical Society of Japan, Vol.57, No.5, October 2005, pp. 821-826. <https://ui.adsabs.harvard.edu/abs/2005PASJ...57..821H/abstract>.
3. Keel, W. C.; Oswalt, T.; Mack, P. et al. "The Remote Observatories of the Southeastern Association for Research in Astronomy (SARA)." Publications of the Astronomical Society of the Pacific, Volume 129, Issue 971, January 2017, pp. 015002. <https://ui.adsabs.harvard.edu/abs/2017PASP..129a5002K/abstract>.
4. Palmer, C. "Diffraction Grating Handbook." Diffraction Grating Handbook, Eighth Edition, 2020. [https://www.researchgate.net/publication/339913143\\_DIFFRACTION\\_GRATING\\_HANDBOOK\\_eighth\\_edition](https://www.researchgate.net/publication/339913143_DIFFRACTION_GRATING_HANDBOOK_eighth_edition).

KEYWORDS: Moderate Resolution Spectrometer; Telescope; Data Collection; Photometric; Stellar Spectra; Moderate Aperture

# VERSION 5

N212-135      TITLE: Development of a Widely Applicable Supporting Optical Circuit in Micro Optics

RT&L FOCUS AREA(S): Hypersonics;Microelectronics

TECHNOLOGY AREA(S): Battlespace Environments;Electronics;Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop a widely applicable supporting optical circuit in micro optics to address the supporting optical circuit building block.

DESCRIPTION: The optical circuit should provide single, polarization-maintaining input fiber and output fiber, for integration into a gyro assembly. The input fiber would bring broadband light, typical for Interferometric Fiber-Optic Gyro (IFOG) operation, into the package. The optical circuit should provide dual photo detectors, one for sampling and monitoring the input light source and the other serving as the detector for the returned, interfered light from the IFOG optical coil and phase modulator. The output fiber will be bi-directional. Internal to the package there must be a means of directing the input light out onto the output fiber and directing the light returning through the output fiber onto the photo detector. The final circuit should be capable of surviving shock, vibration, and thermal excursions typical of aircraft or missile flight. While some performance specifications may need to be altered, depending on desired gyro performance, a re-usable architecture, assembly methodology, and supply chain would be of great value. As an initial prototype, the target is a 14-butterfly package, making the integration of readout electronics with the internal photo diodes as simple as soldering down the component. Future packaging options will be investigated in later phases.

The outcomes of the proposed work are:

- 1) Closed, hardened optical circuits with sources and detectors on chip to operate an IFOG optical coil.
- 2) Defined, documented interfaces between micro-optical and electrical components to facilitate rapid, simplified designs of optical/electronic devices and circuits.

The Phase I effort will not require access to classified information. If need be, data of the same level of complexity as secured data will be provided to support Phase I work. The Phase II effort may require secure access, if so SSP will process the DD254 to support the contractor for personnel and facility certification for secure access.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent

# VERSION 5

requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

**PHASE I:** The Phase I effort will consist of proof-of-concept assembly of micro-optical circuits utilizing photodetectors and light sources for the operation of an IFOG system. A laboratory-scale prototype will be constructed incorporating two photodetectors; a broadband light source, all requisite electrical and optical circuitry, and fiber optic patch cables for exterior connections. The function of the circuit will be demonstrated with a surrogate IFOG. The Phase I Option, if exercised, will include single-board packaging of the optical/electronic circuit, as well as requisite tests to confirm function of the device.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** The Phase II effort will consist of the construction of a ruggedized single-board optical/electronic circuit. The device will incorporate sufficient insulation, vibration isolation, shock and crush protection, and thermal management to operate in conditions characteristic of aircraft or missile flight. Platform surrogate testing will be utilized to verify performance under these conditions. The device will function as a standalone item, excepting input and output to the IFOG or surrogate system. In addition, its exterior interfaces will be sufficiently universal to allow incorporation of a variety of mounting hardware, computer interfaces, and IFOG devices. The architecture of the system will be well documented to facilitate modification and future development. Prepare a Phase III development plan to transition the technology for Navy use and potential commercial use.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

**PHASE III DUAL USE APPLICATIONS:** Phase III will focus on transitioning the product into the final system (for Navy purposes the hypersonic glide-body). Refinement will be focused on integration of the product. Single-board optical/electronic circuits, particularly those with rugged interfaces, will find use in data processing systems, RF photonic systems, and security and safety control systems in both military and civilian use. Other notable uses include “plug and play” fiber analysis systems.

## REFERENCES:

1. Brown, Gair D.; Ingold, Joseph P.; Spence, Scote and Paxton, Jack G. Jr. “High Impact Shock Testing of Fiber-Optic Components.” *Fiber and Integrated Optics*, 9:4, 1 February 1991, pp. 381-392. <https://www.spiedigitallibrary.org/conference-proceedings-of-spie/1366/0000/High-impact-shock-testing-of-fiber-optic-components/10.1117/12.24710.short>.
2. Kyriakis-Bitzaros, Efstathios D.; Haralabidis, Nilow; Lagadas, M.;Georgakilas, Alexandros; Moisiadis, Y. and Halkias, George. "Realistic End-to-End Simulation of the Optoelectronic Links and Comparison With the Electrical Interconnections for System-on-Chip Applications." *J. Lightwave Technol.*, 19.10, 1 October 2001, pp. 1532-1543. <https://www.osapublishing.org/jlt/abstract.cfm?uri=jlt-19-10-1532>.
3. Biere, M.; Gheorghe, L.; Nicolescu, G.; O'Connor, I. and Wainer, G. "Towards the High-Level Design of Optical Networks-on-Chip. Formalization of Opto-Electrical Interfaces." 14th IEEE International Conference on Electronics, Circuits and Systems, 1 January 2008, pp. 427-430. [https://www.researchgate.net/publication/4321257\\_Towards\\_the\\_High-Level\\_Design\\_of\\_Optical\\_Networks-on-Chip\\_Formalization\\_of\\_Opto-Electrical\\_Interfaces](https://www.researchgate.net/publication/4321257_Towards_the_High-Level_Design_of_Optical_Networks-on-Chip_Formalization_of_Opto-Electrical_Interfaces).

**KEYWORDS:** Conventional Prompt Strike; Micro-Optics; Optical Circuits; Extreme Shock/Vibration Environments; Thermal Extremes; Re-usable Architecture; Interferometric Fiber-Optic Gyro; IFOG; IFOG Performance; Phase Modulators; IMU Optimization; 14-Butterfly Package



# VERSION 5

N212-136 TITLE: Development of Predictive Aero-Optical Models of the Hypersonic Environment

RT&L FOCUS AREA(S): Hypersonics;Space

TECHNOLOGY AREA(S): Battlespace Environments;Information Systems;Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop predictive aero-optical models for the hypersonic environment.

DESCRIPTION: Optical sensors operating in hypersonic vehicles are subject to environments which distort the images and light such sensors seek to capture. Three main categories of distortions exist:

- 1) Unsteady distortions, such as turbulence, that lead to random image blur
- 2) Steady distortions, such as shock waves, that lead to systematic image tilts
- 3) Background radiation/optical emission that can degrade the signal to noise ratio

Each of these image distortions represents a risk for developing a hypersonic imaging system that must be reduced with validated predictive models and experiments. This work will develop such validated predicted models.

The outcomes of the proposed work are:

- 1) Databases that contain aero-optical environmental characteristics predicted for an entire flight trajectory.
- 2) Predictive models which can be applied to specific hypersonic vehicles

The Phase I effort will not require access to classified information. The Phase II effort will require secure access. SSP will process the DD254 to support the contractor for personnel and facility certification for secure access.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Develop a model for a range of unclassified hypersonic environmental conditions, including Mach number, altitude, and vehicle angle of attack. Characterize the aerodynamics of the vehicle wake and conduct aero-optical analysis of light passing through the wake. Aero-optical experiments, such as wind-tunnel tests, will also be conducted to validate models against experimental data. Models will be further validated against existing literature. Focus on the environment surrounding the wake of a hypersonic



## VERSION 5

vehicle. Characterize unsteady effects, such as turbulence, steady effects, such as systematic optical deflection through fluid boundary layers, and identify the spectral wavelengths and absolute power of background photon emission. Validate models with wind-tunnel testing experiments.

The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Leverage the models developed during Phase I for application to classified trajectory points of interest. Aerodynamic analysis of the wake in the classified environment will be conducted, as will optical analysis of light passing through this wake. The radiative effects of the classified hypersonic environment will be considered. The vehicle sensor window will also be analyzed using parametric studies to provide further data on potential optical aberrations. The product of this work will consist of databases that contain aero-optical environmental characteristics predicted for the entire flight trajectory.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Utilize the developed models for application in classified points of interest and trajectories. The verified models will be provided to the national community for use in optic sensor development. Work with the Government to transition this database that contains aero-optical environmental characteristics predicted for the entire flight trajectory. The defense industry with focuses on SLBM, ICBMs, etc. will benefit from this technology as they consider unconventional navigation approaches. Also, future commercial hypersonic vehicle developers will have interest in utilizing these models for development of their products.

### REFERENCES:

1. Boyd, Iain and Mackey, Lauren. "Assessment of Hypersonic Flow Physics on Aero-Optics." AIAA J Aeronautics September 2019, Volume 57, Number 9. <https://arc.aiaa.org/doi/abs/10.2514/1.J057869>.
2. Smits, Alexander and Wyckham, Christopher. "Aero-Optic Distortion in Transonic and Hypersonic Turbulent Boundary Layers." AIAA J Aeronautics, September 2009, Volume 47, Number 9. <https://arc.aiaa.org/doi/abs/10.2514/1.41453?journalCode=aiaaj>.
3. Wang, Meng; Mani, Ali and Gordeyev, Stanislav. "Physics and Computation of Aero-Optics." Annual Review of Fluid Mechanics, January 2012, Volume 44, p. 299-321. <https://www.annualreviews.org/doi/abs/10.1146/annurev-fluid-120710-101152>.

KEYWORDS: Conventional Prompt Strike; Aero-Optics; hypersonic environments; optical distortion; background radiation; predictive models; optical sensors

# VERSION 5

N212-137      TITLE: High Efficiency, Low Size Weight and Power (SWaP) Solid State Power Amplifiers (SSPAs) for Sensor Applications

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR);Hypersonics

TECHNOLOGY AREA(S): Battlespace Environments;Sensors;Weapons

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop size-constrained solid-state power amplifier for future Navy radar applications that can operate in extreme environments.

DESCRIPTION: Radar (radio detection and ranging) imaging provides several advantages compared to optical imaging, including all-weather/day-or-night sensing capability. It often has lower resolution than optical techniques; however, the ability to coherently combine multiple samples across synthetic apertures can mitigate some resolution limitations. Additionally, the ranging aspect of radar allows information regarding the distance to objects in a scene as opposed to the simple detection of the objects. For the ranging to occur, a radar system must transmit energy toward a scene of interest and receive reflected energy from that scene. Radar sensitivity is subject to a number of factors including the size of the transmit and receive antennas, the range to the objects of interest, the amount of transmit power broadcast, the sensitivity of the receive electronics, the frequency of operation, (among other things) and is quantified in the radar range equation to first order.

The power amplifier for the transmitter can be improved to increase radar performance. Solid-state power amplifiers are increasing in their use in a variety of applications. Gallium Nitride (GaN) monolithic microwave integrated circuit (MMIC) technology has been instrumental in the adoption of solid-state power amplifiers for power ranges that previously were only addressable using vacuum electronics such as traveling wave tube amplifiers (TWTAs) [Ref 1-2].

The desired outcome of this work is to develop microwave electronics, specifically a prototype solid-state power amplifier radar transmitter that is capable of operation across a variety of possible radar applications of interest to the U.S. Navy. These include intelligence, surveillance, reconnaissance, weather sensing, search and tracking of objects, and fire control.

Broad performance objectives include:

- Frequency of Operation: approximately 15 GHz to 18 GHz
- RF Saturated Output Power: > 200 W
- Saturated Gain: > 50dB
- Duty Factor: Up to ~35% (but variable)
- Pulse Widths: 1  $\mu$ s to 300  $\mu$ s
- Power Added Efficiency: > 30% (at Psat)
- Mechanical Shock: > 1,000 G (relatively few events)
- Size: < 75 in<sup>3</sup>
- Mass: < 8 lbs

## VERSION 5

- Cooling Method: Conduction

Better performance than requested in any or all of the areas listed above may simplify system trades, enable additional capability or open new opportunities for the developed amplifier. As such, improved functionality is welcome and desired. The winning proposed effort may require a MMIC development effort to achieve the desired efficiency over the frequency range of operation, and strong microelectronics packaging expertise to achieve the objective integration density and maintain the efficiency provided by highly-efficient MMIC amplifiers when multiple amplifiers are combined.

The Phase I effort will not require access to classified information. If need be, data of the same level of complexity as secured data will be provided to support Phase I work. The Phase II effort may require secure access, if so SSP will process the DD254 to support the contractor for personnel and facility certification for secure access.

Work produced in Phase II may become classified. Note: The prospective contractor(s) must be U.S. owned and operated with no foreign influence as defined by DoD 5220.22-M, National Industrial Security Program Operating Manual, unless acceptable mitigating procedures can and have been implemented and approved by the Defense Counterintelligence Security Agency (DCSA). The selected contractor must be able to acquire and maintain a secret level facility and Personnel Security Clearances, in order to perform on advanced phases of this project as set forth by DCSA and SSP in order to gain access to classified information pertaining to the national defense of the United States and its allies; this will be an inherent requirement. The selected company will be required to safeguard classified material IAW DoD 5220.22-M during the advanced phases of this contract.

PHASE I: Conduct a feasibility study and initial design effort to provide anticipated performance for the subject power amplifier parameters detailed in the Description. Develop and communicate plans for producing an amplifier prototype in Phase II, including engaging any potential vendors, partners or suppliers the small business contractor may require to complete the anticipated work. The Phase I Option effort, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

PHASE II: Produce and demonstrate through testing a prototype power amplifier capable of meeting the performance goals of the effort. The results should be correlated to current state-of-the-art capabilities. Provide a plan for application-specific qualification testing. Prepare a Phase III development plan to transition the technology for Navy use and potential commercial use.

It is probable that the work under this effort will be classified under Phase II (see Description section for details).

PHASE III DUAL USE APPLICATIONS: Work with the Navy to transition the amplifier technology to the target program. High-efficiency power amplifiers with wide frequency bandwidth may enable multiple simultaneous missions from a single antenna aperture, when paired with flexible exciters, including software-defined radios. Such multi-mission power amplifiers may have more widespread Government use and address defense industries with specific interest in radar applications in extreme environments, such as SLBMs, ICBMs and future commercial hypersonic vehicle developers.

### REFERENCES:

1. Song, Kaijun; Zhang, Fan; Hu, Shun Yong; and Fan, Yizhi. "Ku-band 200-W pulsed power amplifier based on waveguide spatially power-combining technique for industrial applications." IEEE Transactions on Industrial Electronics 61, 8, 1 August 2014, pp. 4274-4280. [https://www.researchgate.net/publication/260521677\\_Ku-band\\_200-](https://www.researchgate.net/publication/260521677_Ku-band_200-)

## VERSION 5

W Pulsed Power Amplifier Based on Waveguide Spatially Power-Combining Technique for Industrial Applications.

2. Feurerschutz, Philip; Rave, Christian; Samis, Stanislav; and Friesicke, Christian. “Active Multi-Feed SATCOM Systems with GaN SSPA at K-band.” German Microwave Conference (GeMiC), 1 March 2016. [https://www.researchgate.net/publication/301800436\\_Active\\_multi-feed\\_satcom\\_systems\\_with\\_GaN\\_SSPA\\_at\\_K-band](https://www.researchgate.net/publication/301800436_Active_multi-feed_satcom_systems_with_GaN_SSPA_at_K-band).

KEYWORDS: Conventional Prompt Strike; Radar; Solid State Power Amplifier; GaN MMIC; Microwave Electronics; Microelectronics; Transmitters; Microwave Power Modules; monolithic microwave integrated circuit

# VERSION 5

N212-138 TITLE: Advanced Persistent-Surveillance Sky Camera

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Electronics;Materials / Processes;Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

**OBJECTIVE:** Develop and demonstrate an Advanced Persistent-Surveillance Sky Camera by enhancing the Wide Area Staring Photometer (WASP), currently in use by United States Naval Observatory (USNO), to be accurate within milli-arcseconds and include simultaneous, multi-filter photometry that has associated star brightness variability estimates valid for at least one year.

**DESCRIPTION:** Wide-field, non-tracking Commercial Off-the-Shelf (COTS) Digital Single Lens Reflex (DSLR) camera arrays that observe many square degrees of the sky are now in use by USNO and other Government agencies. These camera systems are critical for the long-term photometric monitoring of bright stars. They can also be used to observe geostationary satellites and transient celestial events and objects. Because these systems utilize COTS cameras, which are not designed for astronomical use, they are limited in terms of their accuracies and photometric capabilities. USNO desires to develop the next generation of camera systems ("WASP 2.0") that are more astrometrically accurate, more compact, sensitive to a wider range of stellar magnitudes, and include simultaneous, multi-filter photometry. This will benefit Navy by providing relatively inexpensive yet highly capable systems for the long-term monitoring of stars. Since these systems observe large swaths of the sky, they will allow USNO to obtain better measurements of the long-term brightness variability of stars. USNO anticipates that they will be readily deployable around the world, on land sites, as well as ocean surface vessels. This is critical to support observations of stars in both northern and southern hemispheres. Moreover, these systems support other defense applications (e.g., space situational awareness) as well as general astronomical purposes; thus, their commercialization potential is expected to be high. All work executed under this topic will be unclassified.

**PHASE I:** Develop and define a concept design for an Advanced Persistent-Surveillance Sky Camera by enhancing the current WASP to be more astrometrically accurate (at least a degree of magnitude better) with simultaneous, multi-filter photometry. The new WASP 2.0 system will be designed to have the capability to measure astrometric parameters at the milli-arcsecond level and have derivative estimates of brightness variability that are viable for at least one year. Work with the Navy in understanding size, function, and interface requirements for WASP 2.0. Interface requirements will be furnished after Phase I has been awarded. Construct hardware and software that ensure data and network connection integrity as well as USNO data application. Identify risks to the proposed concept, and develop Phase II plans that include ways to mitigate those risks. The Phase I Option, if exercised, will include the initial design specifications and capabilities description to build a prototype solution in Phase II.

**PHASE II:** Produce and deliver a prototype WASP 2.0 camera system. Work with the Navy to fully understand the data and interface requirements. Work with the Navy to understand hardware and integration standards for WASP 2.0 being deployed and used in a manner useful for USNO data constructions as well as NSWCCD data utility. Provide testing scenarios that ensure operational use of data collection

## VERSION 5

efficiencies compared to current practice. Establish a feedback loop with the Navy for implementing changes during prototype testing. All the work under this Phase II effort will be unclassified.

**PHASE III DUAL USE APPLICATIONS:** Deliver a WASP 2.0 camera system to be integrated for operational use by USNO in a manner that supplies data collections needed for SP23 developed capabilities. Provide design and test cases that demonstrate integration of the WASP 2.0 camera in USNO-designed operational environments. Support on-site testing and work with the Navy in the operational set up of the camera system including troubleshooting plus resolving implementation and execution issues at various Navy, DoD, and civilian telescope observatories that can provide information for star tracker navigation. Coordinate with Navy guidance technical teams to leverage stellar data streams that will enhance the design trade space for other guidance and navigation capabilities for these other DoD programs.

In addition to including simultaneous, multi-filter photometry, the next generation of camera systems (“WASP 2.0”) are expected to be more astrometrically accurate, more compact, and more sensitive to a range of stellar magnitudes as compared with current COTS cameras. These systems observe large swaths of the sky, and it is anticipated that they will be readily deployable around the world, on land sites, as well as ocean surface vessels. The increased capability and portability make these cameras an attractive option to users outside of the military.

### REFERENCES:

1. Dao, Phan et al. “Machine Classification and Sub-Classification Pipeline For GEO Light Curves.” Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS) 2019. <https://amotech.com/TechnicalPapers/2019/Machine-Learning-for-SSA-Applications/Dao.pdf>.
2. Dao, Phan and Monet, Dave. “GEO Optical Data Association with Concurrent Metric and Photometric Information.” Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS) 2017. <https://amotech.com/TechnicalPapers/2017/Poster/Dao.pdf>.
3. Ackermann, Mark et al. “COTS Options for Low-Cost SSA.” Advanced Maui Optical and Space Surveillance Technologies Conference (AMOS) 2015. <https://amotech.com/TechnicalPapers/2015/Poster/Ackermann.pdf>.
4. Law, Nicholas M. et al. 2015, “Evryscopescience: exploring the potential of all-sky gigapixel-scale telescopes.” arXiv Labs. arXiv preprint arXiv: 1501.03162. <https://arxiv.org/pdf/1501.03162.pdf>.
5. Abraham, Roberto G. and van Dokkum, Pieter G. “Ultra-low surface brightness imaging with the dragonfly telephoto array.” Publications of the Astronomical Society of the Pacific, 2014, 126(935):55. <https://arxiv.org/pdf/1401.5473.pdf>.

**KEYWORDS:** Sky Camera; Bright Star Variability; Data Collection; Photometric Monitoring; Multi-filter Photometry; Astrometry; Astrometric; Wide Area Staring Photometer; WASP

# VERSION 5

N212-139 TITLE: Radiation Hard Mid-Wave Infrared Imagers

RT&L FOCUS AREA(S): General Warfighting Requirements (GWR)

TECHNOLOGY AREA(S): Electronics;Materials / Processes;Sensors

The technology within this topic is restricted under the International Traffic in Arms Regulation (ITAR), 22 CFR Parts 120-130, which controls the export and import of defense-related material and services, including export of sensitive technical data, or the Export Administration Regulation (EAR), 15 CFR Parts 730-774, which controls dual use items. Offerors must disclose any proposed use of foreign nationals (FNs), their country(ies) of origin, the type of visa or work permit possessed, and the statement of work (SOW) tasks intended for accomplishment by the FN(s) in accordance with section 3.5 of the Announcement. Offerors are advised foreign nationals proposed to perform on this topic may be restricted due to the technical data under US Export Control Laws.

OBJECTIVE: Develop radiation hardened mid-wave infrared (MWIR) sensors for strategic applications.

DESCRIPTION: The performance requirements for MWIR image sensors used in strategic navigation applications continue to become more stringent, necessitating continued innovation for image sensor technologies. Examples of existing research for MWIR imaging sensor technology can be found in the referenced articles [Ref. 1-3]. The applications are also expanding, leading to a need for larger pixel counts and smaller pixels in MWIR imagers. Conventional MWIR sensors have large pixels making large arrays prohibitively expensive.

Commercial applications for MWIR are far reaching, with some examples being stress identification in materials, human tracking/security and automotive and machine industries. This technology would enable devices to be used at higher temperatures in a wider range of environments.

In terms of idealities, these MWIR sensors should have low-noise readout preferably with minimal cooling (e.g., High Operational Temperature (HOT) sensor), have high-density ( $\leq 8 \mu\text{m}$ ) pixel pitch, be radiation-hard at strategic levels, have low power consumption, and be able to be fabricated using foundry processes.

PHASE I: Perform a design and performance modeling study aimed at MWIR sensors with improved performance for strategic sensors as compared to the current state-of-the-art. Assess performance and environmental sensitivity of parameters including responsivity, speed, noise, and defective pixels. Consider all aspects of fabrication and justify the feasibility/practicality of the approach. A goal of quantum efficiency greater than 40% and operability greater than 95% of pixels is desired. Propose, in a Phase II plan, a specific device design for fabrication based upon this analysis.

PHASE II: Fabricate and characterize a small number of prototype MWIR sensors (Up to Qty: 3). Characterization using EMVA1288 standard, shall comprise various parameters including responsivity, speed, noise, and defective pixels in relevant radiation environments. The prototypes should be delivered by the end of Phase II.

PHASE III DUAL USE APPLICATIONS: Continue development to lead to production of MWIR sensors. Production level applications would be highly sought for military seeker applications, strategic needs as well as commercial applications. An image sensor that can meet the stringent performance requirements of strategic instrumentation is likely to bring value to many existing commercial applications. MWIR can be used in the commercial sector for a variety of reasons including stress identification in materials, human tracking/security, and automotive and machine industries. This technology would enable devices to be used at higher temperatures in a wider range of environments.



## VERSION 5

### REFERENCES:

1. Morath, C.; Cowan, M.; Treider, L.; Jenkins, G.; and Hubbs, J. "Proton Irradiation Effects on the Performance of III-V Based, Unipolar Barrier Infrared Detectors." IEEE Transactions on Nuclear Science, Vol. 62, No. 2, 2015. <https://ieeexplore.ieee.org/document/7047245>.
2. Hoglund, L.; Ting, D.; Soibel, A.; Fisher, A.; Khoshakhlagh, A.; Hill, C.; Keo, S.; and Gunapala, S. "Minority carrier lifetime in mid-wavelength infrared InAs/InAsSb superlattices: Photon recycling and the role of radiative and Shockley-Read-Hall recombination mechanisms." Applied Physics Letters 105, 193510, 2014. <https://aip.scitation.org/doi/10.1063/1.4902022>.
3. Soibel, A.; Rafol, B.; Khoshakhlagh, A.; Nguyen, J.; Hoglund, L.; Fisher, A.; Keo, S.; Ting, D.; and Gunapala, S. "Proton radiation effect on performance of InAs/GaSb complementary barrier infrared detector." Applied Physics Letters 107, 261102, 2015. <https://aip.scitation.org/doi/10.1063/1.4938756>.

KEYWORDS: mid-wave infrared sensor; seeker; navigation; image sensor; radiation-hard; imagers; MWIR